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RANGER BLOCK III  
PRELIMINARY TRAJECTORY  
CHARACTERISTICS

Launch Dates from January to June 1965



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JET PROPULSION LABORATORY  
CALIFORNIA INSTITUTE OF TECHNOLOGY  
PASADENA, CALIFORNIA

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CHARACTERISTICS

Launch Dates from January to June 1965

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## FOREWORD

Preliminary trajectories are presented in EPD-132 (Ref. 1) for launch dates between October 1963 and June 1964, and in EPD-212 (Ref. 2) for launch dates between July and December 1964. This document, PD-19, extends EPD-132 and EPD-212 with preliminary trajectories for launch dates from January through June 1965.

## I. INTRODUCTION

## A. Mission

The primary objective of the Ranger Block III mission is the acquisition of knowledge about lunar topography sufficient to determine the gross effect on manned and unmanned lunar landing vehicles. This objective will be achieved by taking relatively high-resolution photographs of various landing areas from an impacting spacecraft.

## B. Ascent Trajectory

The Ranger Block III spacecraft will be launched from the Atlantic Missile Range, Pad No. 12, at a launch azimuth between 90 and 114 deg east of true north. The launch vehicle is the same as those of Ranger Block I and II, consisting of a GD/A Atlas D Mod. II first stage, a Lockheed Agena B second stage, and the JPL Ranger spacecraft as the payload. The spacecraft are similar to those of Ranger Block II with the exception that the Aeroneutronics lunar capsule is replaced with a set of television cameras built by the Radio Corporation of America.

The ascent trajectory for the Ranger Block III mission will be similar to those of Ranger Block I and II in that the parking orbit concept will be used. In a parking orbit trajectory (Fig. 1), the vehicle first enters a low-altitude, circular, Earth-satellite trajectory, coasts in this satellite orbit for a predetermined period, and subsequently leaves this orbit by the application of a final impulse. Such parking orbits effectively diminish the geometrical constraints of a fixed launch site by permitting injection to occur at any point over the Earth's surface and still provide good payload capability. The parking orbit altitude for Ranger Block III will be 100 nm.

## II. POSTINJECTION TRAJECTORY DESIGN CRITERIA

### A. General

The postinjection trajectory design criteria for the Ranger Block III mission stem from four principal areas: attitude control, scientific mission, telecommunications, and temperature control. The design criteria are enumerated in paragraphs B through F.

### B. Attitude Control

The attitude control design criteria (Ref. 3) are as follows:

1. The spacecraft must be in sunlight from 1 hr prior to the Earth acquisition command and continuously, thereafter.
2. The entire lighted portion of the Earth, as seen from the spacecraft, must be contained within the angular range from 32 to 148 deg relative to the probe-Sun line at the time of the Earth acquisition command. This corresponds to an Earth-probe-Sun angle (EPS) constraint of 40 to 145 deg at a range of 64,000 km. The Earth light incident on the spacecraft at the time of acquisition must be greater than 0.7 ft candles.
3. The entire lighted portion of the Earth, as seen from the spacecraft, must be contained within the angular range from 43.5 to 137 deg relative to the probe-Sun line at the time of the earliest possible midcourse maneuver and continuously thereafter. This corresponds to an EPS angle constraint of 46 to 135 deg at a range of 150,000 km.
4. The EPS angle must be greater than 47 deg prior to the time of terminal maneuver.
5. The Earth light incident at the spacecraft must be between 0.06 and 40 ft candles from Earth acquisition to the end of the mission.
6. The magnitude of the terminal maneuver second pitch turn shall be between -47 and +55 deg.
7. At the end of the mission the Earth-probe (near-lighted limb of Moon) angle must be greater than 15 deg.

### C. Scientific Mission

1. Impact locations (Ref. 4) should be contained between  $\pm 20$  deg of the lunar equator.
2. Impact locations should be between 20 and 35 deg from the terminator within the lunar lighted disc visible from Earth.
3. The subsolar point should be between 235 and 320 deg selenographic east longitude.

NOTE: Items 1, 2, and 3 are desirable based on existing knowledge of the TV performance. However, these constraints may be relaxed, depending on mission philosophy and the evaluation of final flight system calibrations.

4. The injection energy shall be such that the transit time from injection to lunar impact shall be nearly constant for any launch period. The transit time may vary between launch periods.
5. The transit time shall be selected so that the lunar impact for all trajectories in a single launch period shall be centered near the zenith of the Goldstone tracking station.

### D. Telecommunications

The Goldstone station-probe-Sun (SPS) angle from the completion of Sun acquisition to the end of the first Goldstone viewing period, excluding the period of the midcourse maneuver, shall lie within the following ranges (detailed plot of Ref. 5):

1.  $28 < SPS < 176$  deg for  $10,000 <$  slant range  $< 40,000$  km
2.  $30 < SPS < 160$  deg for  $40,000 <$  slant range  $< 70,000$  km
3.  $38 < SPS < 140$  deg for  $70,000 <$  slant range  $<$  lunar impact

### E. Temperature Control

1. The allowable time spent in the Earth's shadow during transit to the Moon is a function of the time at which the probe enters the shadow (Ref. 5) and shall lie within the following ranges (detailed plot of Ref. 6):

- a.  $0 < \text{time in shadow} < 47 \text{ min}$ , time of entry = injection  
+2 hr
  - b.  $0 < \text{time in shadow} < 88 \text{ min}$ , time of entry = injection
  - c.  $0 < \text{time in shadow} < 130 \text{ min}$ , time of entry = 1 hr  
before injection
2. It is desirable that the Z-axis of the spacecraft shall be pointed as close as possible to the direction of the Sun during the terminal maneuver.
- F. Miscellaneous Limitations
1. Launch from Cape Kennedy
  2. The maximum launch-azimuth spread shall be from 90 to 114 deg east of true north.
  3. Parking orbit altitude of 100 nm.
  4. The Agena second burn shut-off constant shall be fixed in any one day.  
This implies a nearly constant injection energy during each day.

### III. LAUNCH PHILOSOPHY

#### A. General

The launch problem associated with a lunar impact mission launched from the Earth is complex. Constant changes in the geometry of the celestial bodies require relative change in the launch parameters.

The lunar impact trajectories must satisfy the celestial geometry as well as the constraints listed in Section II, and in doing so, a set of launch parameters evolve. Two of these are launch day and launch time. The permissible launch days define the launch period, and the permissible launch times in any one day define the firing window.

The discussion of launch philosophy is based upon spacecraft considerations only. The spacecraft launch restrictions have been examined carefully in an effort to obtain the longest possible launch period and firing window. Final trajectory analysis may restrict the launch period and firing window further.

#### B. Launch Period

Launch periods for the Ranger Block III mission are determined primarily by the attitude control constraints listed in Section II. B and by the scientific mission constraints in Section II. C.

Figure 2 shows a sketch of the Earth, Moon, and Sun geometry and the positions of the Moon at impact that do not satisfy the attitude control constraints. These positions occur near new and full Moons. As a result, the attitude control constraints dictate two permissible launch periods, referenced about first and third quarters, each having a maximum length of from five to eight consecutive days. Table 1, Section VI, lists the lunar third-quarter launch periods for each month which satisfy the attitude control constraints from July 1964 through December 1965.

The scientific mission constraints dictate which of the two launch periods in any one month is acceptable. In addition, these constraints may restrict the launch period to less than the maximum length of eight days. Figure 3 presents a sketch of the vertical impact geometry of a 66-hr transit time trajectory. The sketch is intended to point out general trajectory characteristics and not the actual shape of the trajectory. For this reason, the

Trajectory is drawn in two separate frames of reference as conic approximations. The transfer orbit is drawn in the inertial Earth reference frame and is a highly elliptical orbit which pierces the lunar sphere of influence. At the piercing point, the reference frame is changed to the inertial lunar reference frame by subtracting the velocity of the Moon relative to the Earth  $\vec{V}_M$  from the velocity of the probe relative to the Earth  $\vec{V}_P$  and obtaining the velocity of the probe relative to the Moon  $\vec{V}_{PM}$ . It has been empirically determined that the velocity vector  $\vec{V}_{PM}$  is very nearly equal to the hyperbolic excess velocity vector  $\vec{V}_\infty$ . Since the selenocentric conic is a rectilinear hyperbola for a vertical impact trajectory, the direction of  $\vec{V}_{PM}$  must pass through the center of the Moon as shown. Furthermore, the Earth-Moon-probe angle at impact is approximately 42 deg, and the velocities  $V_M$ ,  $V_{PM}$ , and  $V_P$  are of the same order of magnitude for a 66-hr trajectory--1 km/sec. This means that the  $\vec{V}_P$  must always point to the left or lunar-west of the Earth-Moon line, and the point of entry into the lunar sphere of influence must always occur to the lunar-west of the Earth-Moon line, such that  $\vec{V}_P - \vec{V}_M$  produces a  $\vec{V}_{PM}$  which passes through the center of the Moon as in Fig. 3. Therefore, all the vertical or near-vertical impact trajectories must impact on the western portion of the lunar surface. In addition, any trajectory which impacts on the eastern portion of the lunar surface must be a nonvertical impacter.

Figure 2 shows that, in order to satisfy the lighting constraint (Section II. C. 2), a vertical impact trajectory which impacts on the lunar-west side must be launched during the third-quarter period. A nonvertical impact trajectory which impacts on the lunar-east side and satisfies the lighting constraint must be launched during the first-quarter period. In addition, it follows that a nonvertical impact trajectory which impacts near the Earth-Moon line, neither east nor west, must be launched within or near the full-Moon period.

Since Ranger Block III trajectories are to impact vertically or near-vertically, the landing area must be on the western portion of the lunar surface, and as a result, launch must occur during the third-quarter period.

There are only two launch days in each third-quarter period in which vertical impact trajectories satisfy the desirable lighting angle constraint. However, by biasing the vertical impact trajectories on additional launch days, the lighting angles can be shifted so that the values will be between the required ranges. These biased trajectories are nonvertical impacters having impact

angles up to 30 deg from the vertical. In this manner, five to eight consecutive days of a third-quarter launch period are obtained.

### C. Firing Window

The firing window is determined by the allowable launch azimuth range. As launch time varies in any one day, the launch azimuth and the parking orbit coast time must also vary in order to compensate for the motions of the Earth and Moon. In this manner, the minimum and maximum values of launch azimuth limit the length of the firing window. The launch azimuth range presented in this report is from 90 to 114 deg. The final permissible launch azimuth range may be reduced at a later date due to range safety, tracking, and/or telecommunication limitations. Table 2 presents a listing of launch times for launch azimuths of 90, 102, and 114 deg for each launch period. By taking the difference between launch times for the 90 and 114 deg cases, the maximum length of firing window is obtained. Figure 4 shows the launch times versus the launch days for each of the maximum launch periods of azimuths from 90 and 114 deg. Figure 5 presents the maximum firing window versus launch day for launchings from January through June 1965.

## IV. TRAJECTORY CHARACTERISTICS

## A. Near-Earth Phase

The Ranger Block III trajectories might be classed as slow trajectories since their flight times are of the order of 66 hr. Choice of flight time is made on the basis of visibility of impact to the Goldstone tracking station and guidance accuracy considerations. The geocentric postinjection trajectories are typical for flight times of this order. They are highly elliptical trajectories which may be described in a general manner by the conic elements at injection. These are as follows: a vis viva energy of  $-1.0 \text{ km}^2/\text{sec}^2$ , an eccentricity of 0.98, a semimajor axis of 388,000 km, an inclination varying from 28 to 36 deg depending on the launch azimuth, a perigee distance of 6563 km, and a true anomaly at injection of 3.3 deg (injection occurs 3.3 deg past perigee). The injection points for this type of trajectory occur over the Atlantic Ocean area between the United States and South Africa. The location of these injection points depends upon the declination of the Moon at lunar impact.

The injection locations for the launch periods considered are shown in Fig. 6 through 11 for trajectories of 90 through 114 deg launch azimuth and for successive days on which firings are permissible. Each line represents the injection locus for the launch date noted. Table 2 gives geocentric injection conditions for each day of the launch.

The Earth tracks for specific launch dates can be estimated by comparing their injection loci (Fig. 6 through 11) with the injection loci of the trajectories whose Earth tracks are shown in Fig. 12, 13, and 14. These three Earth tracks correspond to trajectories which encounter the Moon at declinations of -20, 0 and 21 deg. The DSIF coverage for these Earth tracks is noted.

## B. Cruise Phase

Since the trajectories are designed to allow the spacecraft to impact the Moon during the lunar day, the probe will be in direct sunlight except for brief periods during its travel in the vicinity of the Earth. The spacecraft never enters the shadow of the Moon. The time that the spacecraft spends in the Earth's shadow will vary according to launch date and launch azimuth. The

temperature constraint, dependent on the time spent in the Earth's shadow (Section II, E. 1), is never violated for the launch dates covered by this document. Table 3 presents these shadow events versus time from launch.

The Earth-probe-Sun angles vs. time-from-launch are presented in Fig. 15, 17, 19, 21, 23, and 25 for the launch days and months considered. Also, the Sun-probe-Moon angles are given in Fig. 16, 18, 20, 22, 24, and 26. Note that on May 24, 1965, the maximum Earth-probe-Sun angle constraint of 135 deg is slightly violated, and thus this day could be considered marginal.

To increase the mission reliability of Ranger Block III, a backup timer will be used to activate the TV cameras prior to lunar impact should a failure in the command link preclude initiation of the terminal maneuver sequence. This implies that the time from injection to impact must be nearly constant throughout any one launch period but may vary from launch period to launch period. The constant flight times listed in Table 2 were selected to optimize the view of lunar impact at the Goldstone tracking station. Figure 27 shows the visibility of impact conditions as seen at Goldstone during each launch period for launch azimuths of 90, 102, and 114 deg.

Prior to impact the probe's angular motion relative to the tracking stations is primarily in hour-angle with a rate of approximately 15 deg/hr. This implies that for an hour-angle at impact of -60 deg and an initial pointing capability of -90 deg the probe would be in view at Goldstone during a two-hour interval prior to impact. Errors in time of flight will cause a one-to-one change in the hour-angle of the probe at impact. Thus, for the same example, an error in flight time resulting in an impact one hour early would reduce the viewing interval prior to impact by an hour. Also shown in Fig. 27 are the Goldstone tracking station hour-angles of the probe at impact corresponding to nominal flight conditions on each launch day. The hour-angle constraint is  $\pm 90$  deg; however, for certain declinations of the probe at encounter, the horizon mask is more restrictive. For all cases, the equivalent limiting hour-angle is depicted in the same figure.

### C. Lunar Encounter Phase

The lunar encounter conditions for vertical impact trajectories are presented in Table 2. For an impact location other than vertical, a nonvertical encounter or biased trajectory results. This may occur by design or

circumstance. By designing a nonvertical impact, a location can be selected to enhance the conditions (i. e., better lighting) at encounter. Whether a vertical or nonvertical trajectory is used, the trajectory analysis is the same.

Preliminary studies indicate that the Ranger Block III mission can be successful if, excluding certain marginal areas, the probe impacts within the lunar, lighted disc visible from Earth. The marginal areas are those close to the terminator and/or the subsolar point. Final analysis will be done using calibrations of flight hardware, to define acceptable and unacceptable impact areas.

In order to evaluate a wide range of lunar encounter conditions the following discussion on lunar encounter trajectories is presented.

Ballistic trajectories initiated near Earth can be characterized at lunar encounter by a two-body hyperbolic conic (Fig. 3). The incoming asymptote for a given flight time and encounter day is essentially fixed in its orientation for any close encounter with the Moon. The probe approaches the Moon initially along the incoming asymptote. The geometry is shown in Fig. 28 and 29. The vector  $\bar{B}$  from the center of the Moon to the incoming asymptote  $\bar{S}_I$  represents the massless miss (Ref. 7) or the miss which would occur for a massless Moon. However, the Moon-mass causes the probe to follow a hyperbolic path away from  $\bar{S}_I$  and toward the Moon.

For  $\bar{B}$  vectors less than 4000 km, depending on the energy relative to the Moon, the trajectory will impact the Moon. It follows that for a larger  $\bar{B}$  vector, a flyby trajectory will result. The selenocentric trajectory geometry for impact, and flyby trajectories for energies relative to the Moon corresponding to impact velocities of 2.6, 2.65, and 2.7 km/sec, are presented in Fig. 30 through 35. In these figures, lines of constant time from impact or from closest approach are noted for trajectories of varying miss parameter  $\bar{B}$ . The miss parameter  $\bar{B}$  and incoming asymptote  $\bar{S}_I$  are contained in, and thus define, the orientation of the trajectory plane during lunar encounter. Since the incoming asymptote is essentially fixed for a given flight time and encounter date, the vertical impact location (Fig. 28) will be contained in the trajectory plane relative to the Moon for any miss parameter  $\bar{B}$  about the incoming asymptote. Thus, the geometry for any near-encounter of the Moon can be constructed by combining the trajectory geometry presented in Fig. 30 through 35 with the vertical impact location and the magnitude and orientation of the miss

parameter  $\bar{B}$ . A group of six figures shows the vertical impact locations in relation to the subterrestrial points and the terminator at encounter for the launch dates tabulated in Table 2.

The trajectory geometry at impact may be evaluated from Fig. 28 and 36, which in turn define and relate the impact parameters with the magnitude of the miss parameter  $\bar{B}$ . The impact parameters defined are the bias angle  $\beta$ , the impact angle  $\theta_S$ , and the angle  $\gamma$  turned by the impact velocity vector from the asymptote direction. In addition, Fig. 37 presents  $\theta_S$  and  $\gamma$  vs.  $\beta$ . The variation of velocity and altitude prior to lunar impact as a function of  $\beta$  is given in Fig. 38 through 40.

The deflection angle  $\alpha$  between the incoming asymptote  $\bar{S}_I$  and outgoing asymptote  $\bar{S}_O$ , as well as the closest approach distance  $R_{CA}$ , are presented in Fig. 41 in comparison to the miss parameter  $\bar{B}$ . These flyby trajectory parameters are defined in Fig. 29

Figure 42 through 47 represent the group of six showing the lunar lighting and trajectory geometry at impact.

The selenographic coordinators are graphically defined in Fig. 48.

V. REFERENCES

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6. Katter, L. B., "Restraint of Ranger Trajectories from Thermal Considerations," Interoffice Memorandum, Jet Propulsion Laboratory, March 27, 1962.
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VI. TABLES

Table 1 is a listing, by calendar date, of the maximum number of days that constitute each possible launch period occurring between July 1964 and December 1965.

Table 2 presents the vertical impact trajectory parameters for the six monthly launch periods from January through June 1965, for the 90-, 102-, and 114-deg launch azimuths.

Table 3 presents shadow events for the six monthly periods for the 90-, 102-, and 114-deg launch azimuths.

Table 1. Maximum launch periods for July 1964 through December 1965

Month	Days	Year
July/August	27, 28, 29, 30, 31, 1	1964
August	25, 26, 27, 28, 29, 30	1964
September	24, 25, 26, 27, 28	1964
October	23, 24, 25, 26, 27	1964
November	21, 22, 23, 24, 25, 26	1964
December	20, 21, 22, 23, 24, 25, 26-27	1964
*January	18, 19, 20, 21, 22, 23, 24-25	1965
*February	17, 18, 19, 20, 21, 22-23, 24	1965
*March	19, 20, 21, 22, 23, 24-25, 25-26	1965
*April	18, 19, 20, 21, 22, 23-24, 24-25	1965
*May	18, 19, 20, 21, 22, 23, 24	1965
*June	17, 18, 19, 20, 21, 22	1965
July	16, 17, 18, 19, 20, 21	1965
August	15, 16, 17, 18, 19, 20	1965
September	13, 14, 15, 16, 17, 18	1965
October	13, 14, 15, 16, 17	1965
November	11, 12, 13, 14, 15, 16	1965
December	10, 11, 12, 13, 14, 15-16	1965

These months covered by this report.

Table II. Trajectory parameters for the vertical impact trajectories January through June 1965

Launch date		Launch, 90-deg azimuth				Launch, 102-deg azimuth																Launch, 114-deg azimuth											
		Injection Conditions		Injection Conditions				Impact Conditions												Injection Conditions													
								Launch time GMT	Time GMT	Latitude	Longitude	Flight time from injection	Time GMT	Goldstone viewing		Normal Impact		Selenocentric Subsolar		Subterrestrial				Earth-probe-Sun angle	Speed	Launch time GMT	Time GMT	Latitude	Longitude				
month	day	hr	min	sec	hr	min	sec	deg	deg	hr	min	sec	deg	deg	hr	min	sec	deg	deg	deg	deg	deg	m/sec	hr	min	sec	deg	deg					
Jan 1965	18	14	24	27	14	56	38	-11.99	25.97	16	6	12	16	33	5	-11.95	2.51	66.0	10 33 17	345.06	6.55	-12.04	313.30	-1.01	314.13	-6.70	7.12	53.27	2626	17 33 51	17 56 18	-12.53	341.85
	19	15	57	49	16	27	0	-6.47	15.65	17	35	38	17	59	43	-6.43	353.05	66.0	11 59 2	354.48	0.54	-13.28	315.98	-1.04	301.26	-6.42	7.69	66.60	2631	18 55 2	19 15 5	-7.03	334.24
	20	17	27	11	17	53	30	-0.94	5.96	19	1	25	19	22	48	-0.93	344.17	66.0	13 22 43	3.92	-5.30	-13.82	318.59	-1.07	288.41	-5.76	7.71	79.40	2638	20 12 53	20 30 39	-1.63	327.13
	21	18	54	22	19	17	56	4.38	356.75	20	24	56	20	43	45	4.31	335.77	66.0	14 43 34	12.88	-10.71	-13.66	320.86	-1.09	275.57	-4.80	7.24	91.73	2645	21 28 34	21 44 10	3.48	320.49
	22	20	20	36	20	41	34	9.29	347.90	21	47	15	22	3	41	9.11	327.81	66.0	16 3 23	21.55	-15.50	-12.81	322.58	-1.11	262.73	-3.62	6.36	103.67	2651	22 42 45	22 56 22	8.12	314.33
	23	21	46	14	22	4	47	13.62	339.46	23	8	22	23	38	13.30	320.38	66.0	17 22 36	29.82	-19.49	-11.37	323.61	-1.13	249.89	-2.28	5.17	115.34	2658	23 55 18	0 7 11	12.09	308.81	
Feb 1965	24-25	23	9	37	23	26	3	17.13	331.80	0	26	33	0	38	59	16.65	313.89	66.0	18 38 57	37.04	-22.54	-9.46	323.93	-1.15	237.07	-0.85	3.77	126.79	2663	1 4 50	1 15 19	15.21	304.24
	17	16	25	57	16	50	41	2.10	0.72	17	58	21	18	18	16	2.08	339.35	65.0	11 18 20	353.82	-8.40	-13.78	318.54	-1.48	308.86	-5.04	6.95	58.22	2644	19 5 35	19 22 6	1.34	323.28
	18	17	55	30	18	17	29	7.38	351.40	19	23	58	19	41	20	7.27	330.92	65.0	12 41 16	2.96	-13.67	-13.19	321.01	-1.49	296.00	-3.90	6.60	70.68	2649	20 22 54	20 37 17	6.36	316.69
	19	19	23	56	19	43	21	12.09	342.53	20	47	57	21	2	59	11.84	323.04	65.0	14 2 49	11.65	-18.15	-11.91	322.93	-1.50	283.15	-2.59	5.80	82.74	2655	21 38 7	21 50 37	10.71	310.76
	20	20	50	24	21	7	31	16.02	334.33	22	9	15	22	22	16	15.60	316.00	65.0	15 22 1	19.53	-21.67	-10.06	324.12	-1.51	270.32	-1.18	4.65	94.46	2661	22 50 25	23 1 21	14.23	305.70
	21	22	11	34	22	26	51	18.93	327.47	23	24	47	23	36	15	18.31	310.40	65.0	16 35 59	25.82	-24.11	-7.85	324.89	-1.51	257.52	0.26	3.29	105.92	2667				
	22-23	23	20	42	23	34	52	20.51	323.32	0	29	20	0	39	57	19.72	307.25	65.0	17 39 44	29.37	-25.37	-5.53	324.08	-1.52	244.79	1.67	1.81	117.18	2673				
Mar 1965	24	0	10	20	0	24	31	20.50	323.34	1	18	14	1	28	54	19.65	307.42	65.0	18 28 47	29.20	-25.43	-3.35	323.07	-1.52	232.19	2.98	0.34	128.30	2677				
	19	18	25	55	18	43	52	14.64	337.33	19	42	2	20	0	46	14.30	318.51	64.3	12 18 40	6.07	-20.46	-10.83	322.79	-1.49	303.07	-1.53	4.75	61.79	2660	20 31 42	20 43 10	13.03	307.46
	20	19	52	36	20	8	24	18.12	329.46	21	7	47	21	19	41	17.58	311.96	64.3	13 37 31	13.46	-23.47	-8.63	323.90	-1.49	290.23	-0.06	3.67	73.59	2665	21 43 8	21 53 14	16.04	302.95
	21	21	9	43	21	24	1	20.35	323.75	22	19	9	22	29	50	19.60	307.52	64.3	14 47 39	18.49	-25.27	-6.21	324.21	-1.48	277.46	1.38	2.37	85.10	2671				
	22	22	8	42	22	22	31	21.01	321.91	23	15	21	23	25	43	20.13	306.29	64.3	15 43 36	19.94	-25.83	-3.86	323.77	-1.47	264.80	2.73	0.95	96.36	2677				
	23	22	45	42	23	0	13	20.02	324.64	23	54	18	0	5	16	19.15	308.55	64.3	16 23 13	17.45	-25.18	-1.77	322.77	-1.47	252.27	3.94	359.53	107.46	2682				
	24-25	23	6	15	23	22	22	17.65	330.60	0	19	16	0	31	35	16.84	313.51	64.3	16 49 34	11.91	-23.38	.02	321.37	-1.46	239.85	4.97	358.20	118.50	2685	0 55 30	1 6 0	15.19	304.26
Apr 1965	25-26	23	17	38	23	35	50	14.22	338.20	0																							

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Table III. Shadow parameters

Launch date	Launch, 90-deg azimuth				Launch, 102-deg azimuth				Launch, 114-deg azimuth			
	Enter shadow, TFL	Spacecraft/Agena separation TFL	Exit shadow, TFL	Total time in shadow	Enter shadow, TFL	Spacecraft/Agena separation TFL	Exit shadow, TFL	Total time in shadow	Enter shadow, TFL	Spacecraft/Agena separation TFL	Exit shadow, TFL	Total time in shadow
month day	min	min	min	min	min	min	min	min	min	min	min	min
Jan 1965	18	---	---	0	---	---	---	0	---	---	---	0
	19	---	---	0	---	---	---	0	---	---	---	0
	20	---	---	0	---	---	---	0	---	---	---	0
	21	23.52	26.16	35.77	12.24	18.65	21.43	30.03	11.38	15.56	18.20	23.49 7.93
	22	16.87	23.56	37.01	20.14	12.09	19.03	31.66	19.57	8.99	16.22	26.45 17.47
	23	11.16	21.15	35.55	24.39	8.35*	16.86	30.63	22.28	8.35*	14.49	26.50 18.15
Feb 1965	24-25	8.35*	19.03	32.87	24.52	8.35*	15.03	28.41	20.05	8.35*	13.09	25.29 16.94
	17	---	---	0	---	---	---	0	---	---	---	0
	18	---	---	0	---	---	---	0	---	---	---	0
	19	21.89	22.02	38.67	16.78	17.43	17.63	32.17	14.75	16.64	15.09	21.91 5.28
	20	15.63	19.72	40.58	24.95	11.40	15.62	35.06	23.66	9.35	13.53	29.03 19.68
	21	10.65	17.87	38.21	27.56	8.35*	14.06	33.49	25.14	**	---	---
	22-23	8.35*	16.78	34.80	26.46	8.35*	13.21	30.70	22.34	**	---	---
Mar 1965	24	8.35*	16.78	31.93	23.58	8.35*	13.26	28.16	19.81	**	---	---
	19	---	---	0	---	---	---	0	---	---	---	0
	20	21.10	18.40	51.05	29.95	17.39	14.49	43.65	26.27	18.49	12.71	30.53 12.04
	21	14.70	16.89	48.38	33.67	11.05	13.29	42.86	31.82	**	**	**
	22	11.58	16.42	43.32	31.73	8.35*	12.96	38.93	30.58	**	**	**
	23	9.56	17.12	39.32	29.75	8.35*	13.56	35.32	26.97	**	**	**
	24-25	8.48	18.71	36.91	28.43	8.35*	14.92	32.91	24.56	8.35*	13.10	30.54 22.19
Apr 1965	25-26	8.35*	20.80	35.72	27.36	8.35*	16.77	31.57	23.22	8.35*	14.54	29.10 20.74
	18	22.26	16.17	68.49	46.23	19.05	12.73	60.84	41.80	**	**	**
	19	16.60	16.45	58.28	41.68	13.07	13.00	53.21	40.13	**	**	**
	20	15.05	17.80	51.09	36.04	11.30	14.14	46.60	35.29	9.69	12.50	42.55 32.87
	21	14.49	19.76	46.39	31.90	10.45	15.85	42.06	31.61	8.35*	13.80	38.90 30.55
	22	14.11	22.06	43.69	29.58	9.84	17.92	39.28	29.44	8.35*	15.46	36.24 27.90
	23-24	13.90	24.55	42.20	28.30	9.42	20.22	37.67	28.25	8.35*	17.37	34.49 26.15
May 1965	24-25	13.77	27.18	41.50	27.72	9.12	22.68	36.91	27.79	8.35*	19.47	33.49 25.13
	18	22.83	18.86	71.17	48.34	18.86	15.06	65.75	46.89	17.48	13.19	58.75 41.27
	19	20.43	21.07	61.44	41.02	16.24	17.02	56.44	40.20	13.98	14.73	51.58 37.61
	20	20.29	23.48	55.31	35.01	15.92	19.23	50.40	34.48	13.18	16.54	46.33 33.16
	21	20.21	26.04	51.51	31.30	15.63	21.61	46.68	31.05	12.46	18.54	42.77 30.32
	22	20.12	28.70	49.30	29.18	15.36	24.11	44.41	29.05	11.80	20.70	40.44 28.65
	23	20.04	31.47	48.13	28.09	15.12	26.72	43.15	28.03	11.18	22.96	39.02 27.84
Jun 1965	24	19.96	34.32	47.75	27.79	14.87	29.41	42.64	27.78	10.53	25.29	38.22 27.70
	17	27.60	25.14	73.45	45.84	23.01	20.76	67.82	44.80	20.18	17.82	61.41 41.23
	18	26.24	27.73	65.06	38.82	21.57	23.19	59.73	38.16	18.22	19.90	54.47 36.25
	19	26.46	30.41	59.86	33.40	21.61	25.72	54.57	32.96	17.86	22.08	49.61 31.75
	20	26.38	33.16	56.69	30.31	21.36	28.32	51.38	30.02	17.21	24.33	46.48 29.27
	21	26.27	35.99	54.84	28.57	21.06	30.97	49.46	28.40	16.48	26.62	44.43 27.95
	22	26.09	38.86	53.91	27.82	20.66	33.65	48.41	27.75	15.59	28.88	43.10 27.52

\*Probe in shadow of parking orbit injection; enter shadow time taken as being at this time.

\*\*Parking orbit coast time less than zero.

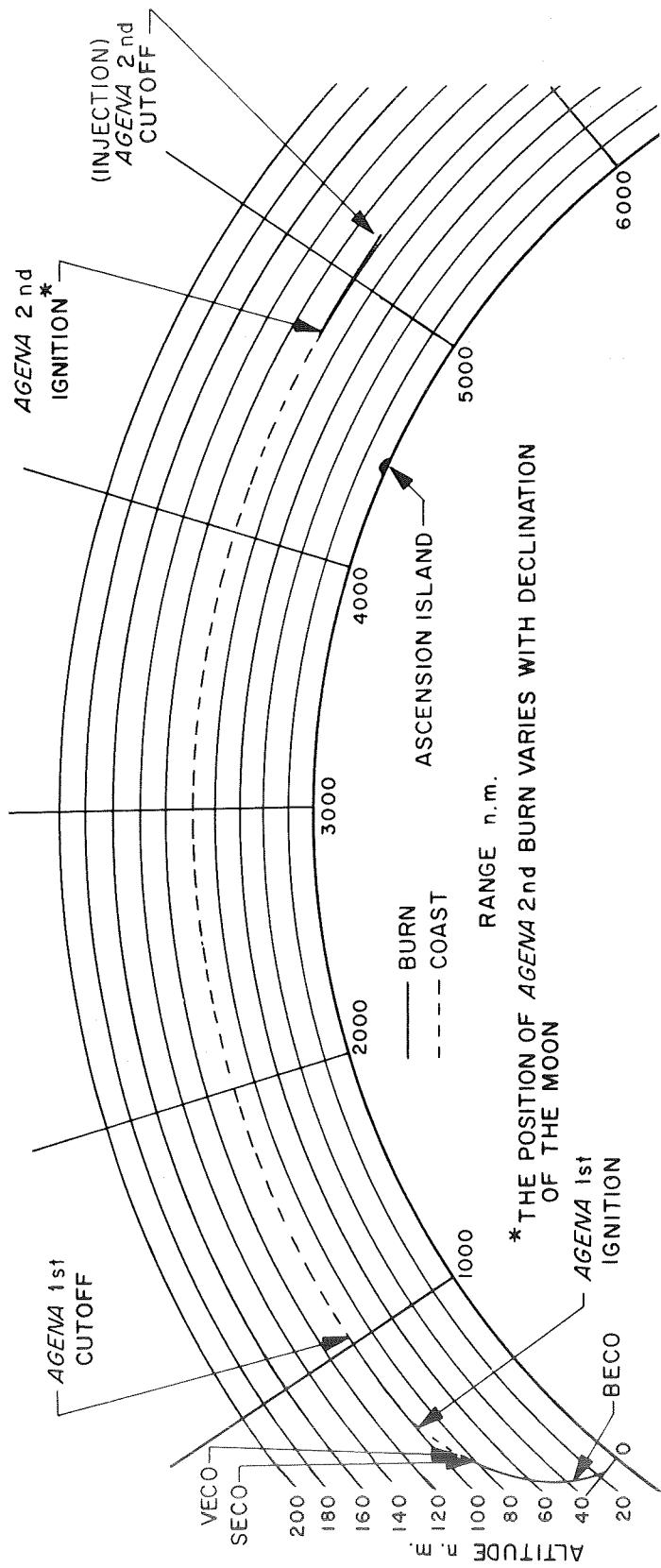


Fig. 1. Ascent trajectory profile

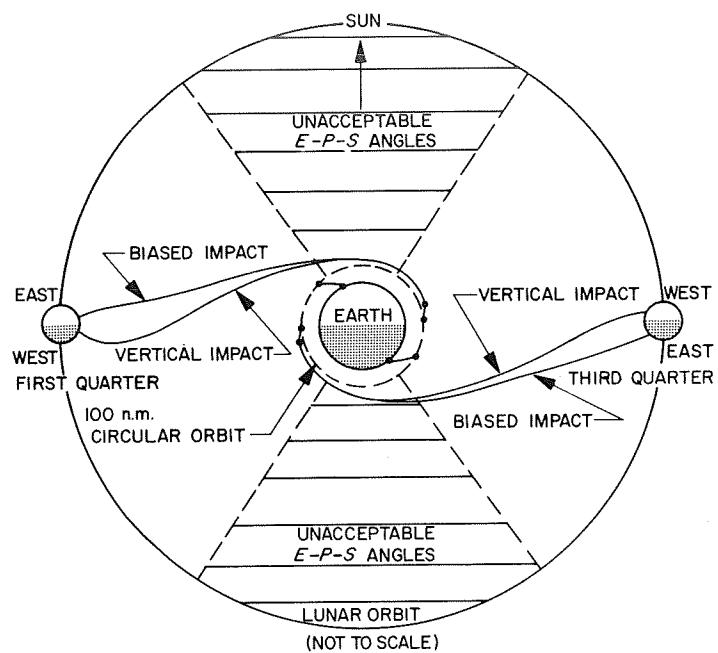
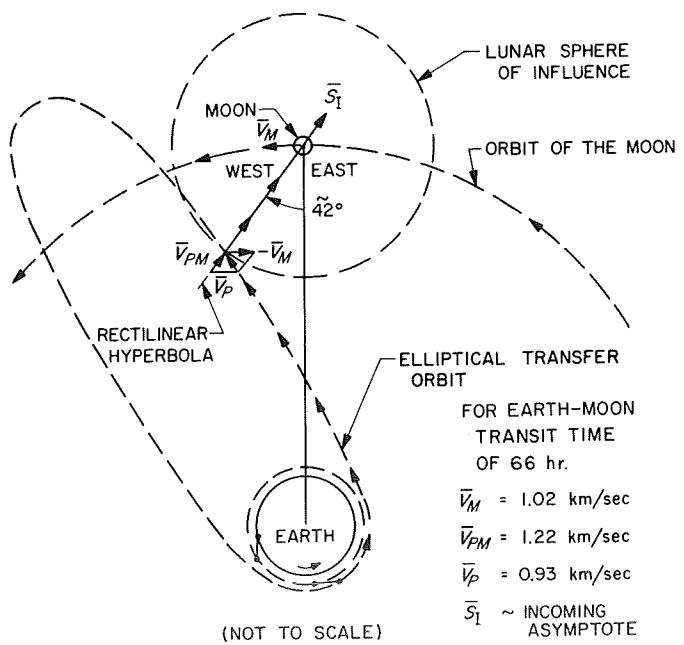


Fig. 2. Lighting angle geometry at impact

Fig. 3. Vertical impact geometry



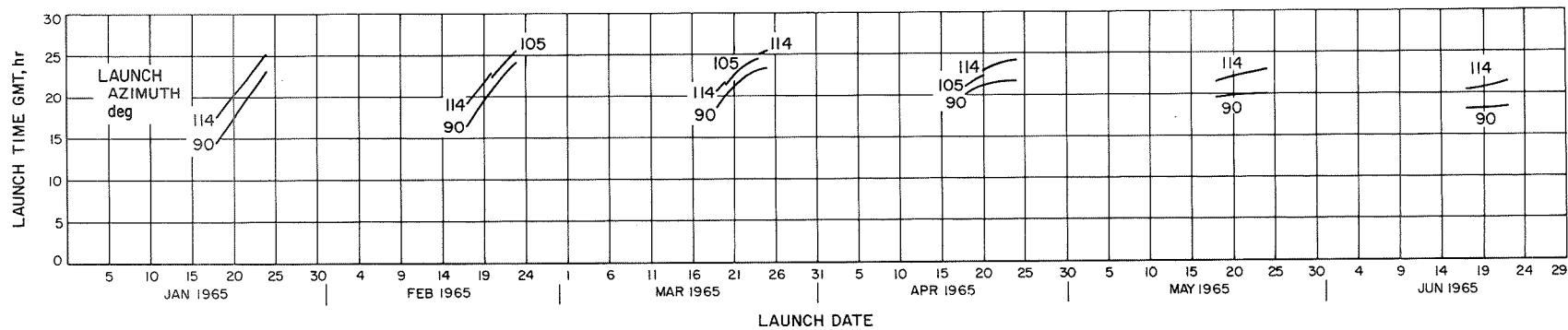


Fig. 4. Launch time vs. launch date

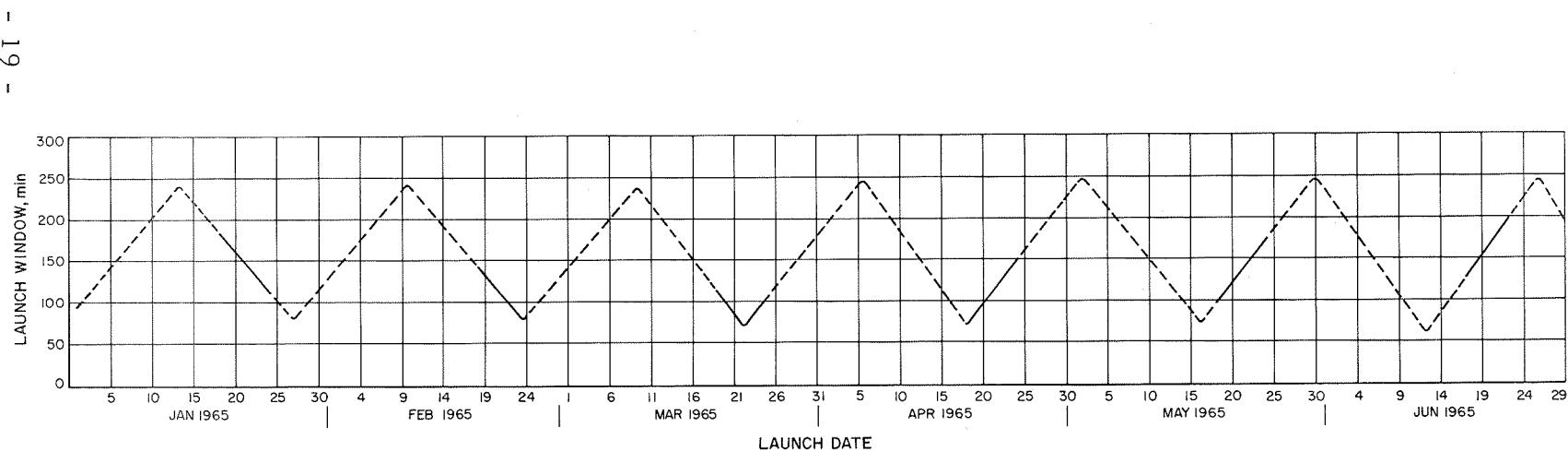


Fig. 5. Maximum firing window vs. launch date

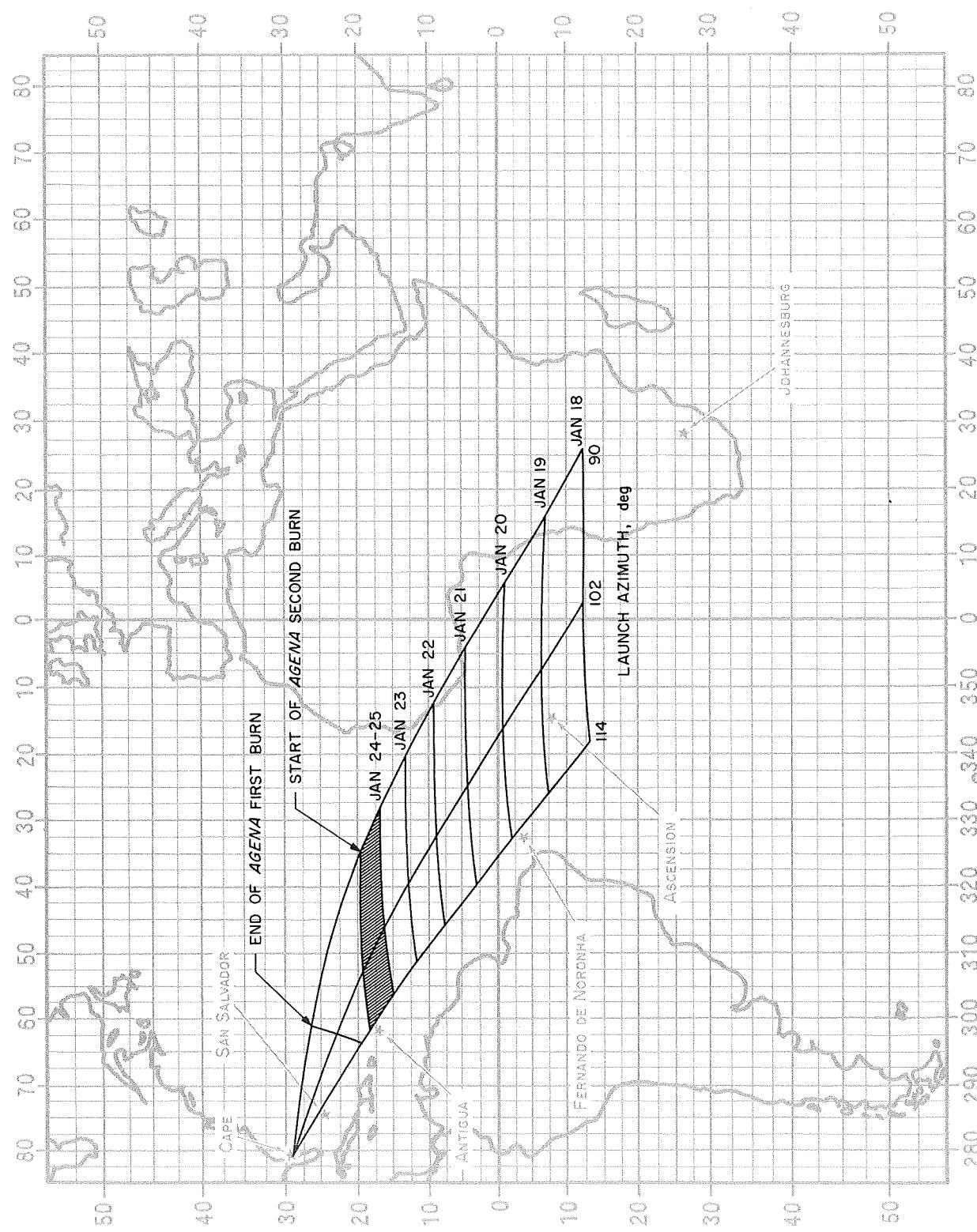


Fig. 6. Ranger injection for January 18 through January 24-25, 1965

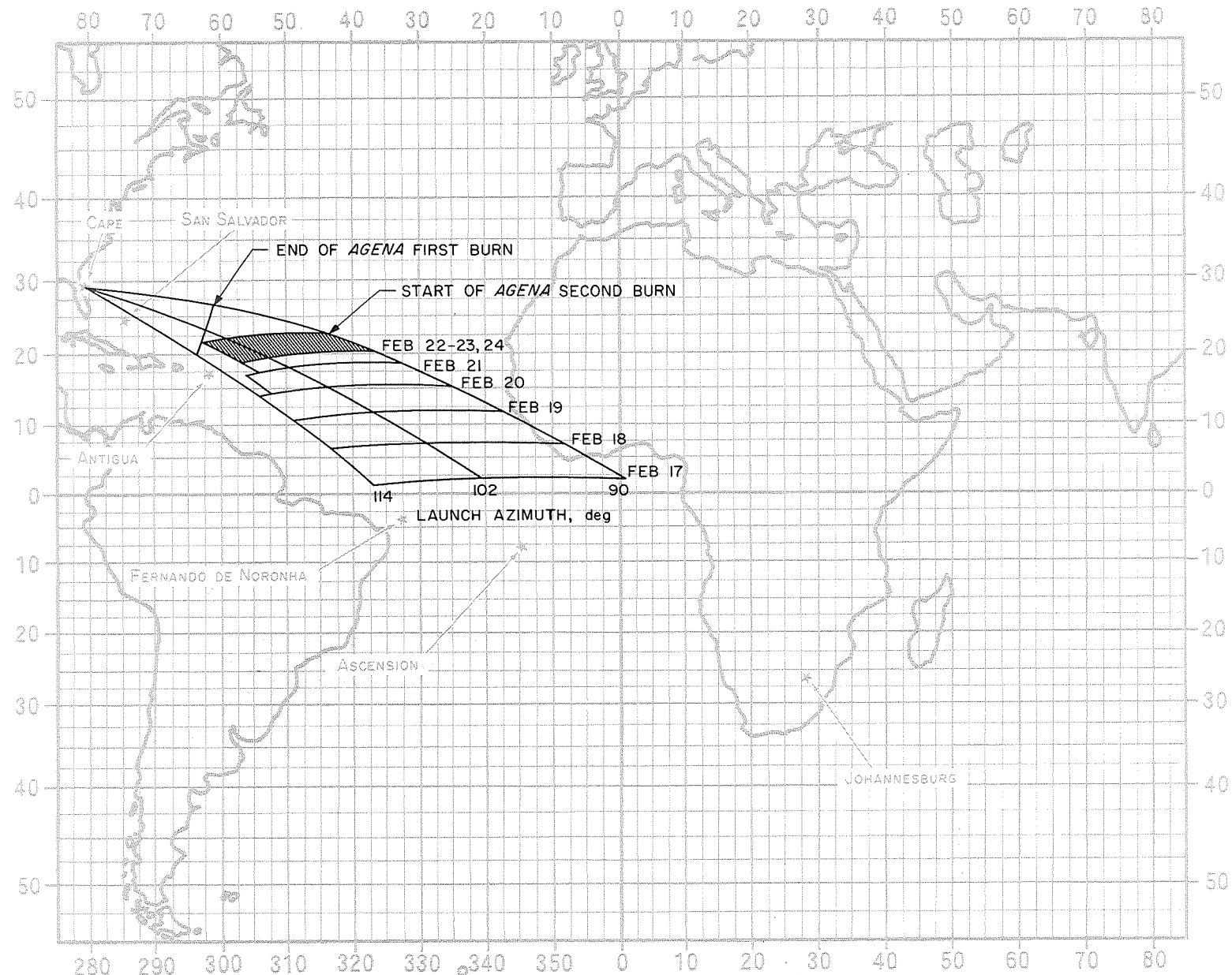


Fig. 7. Ranger injection loci for February 17 through February 24, 1965

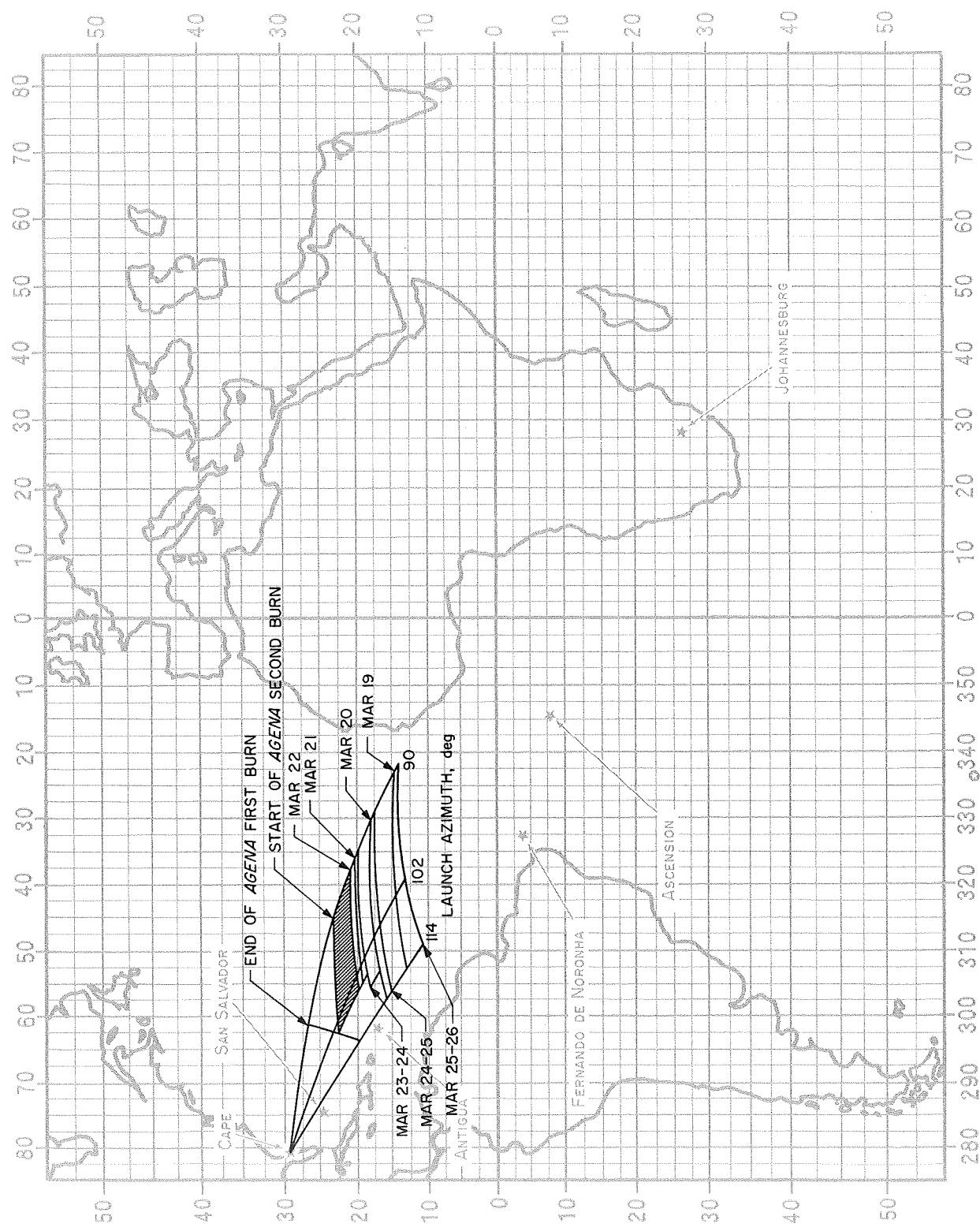


Fig. 8. Ranger injection loci for March 19 through March 26, 1965

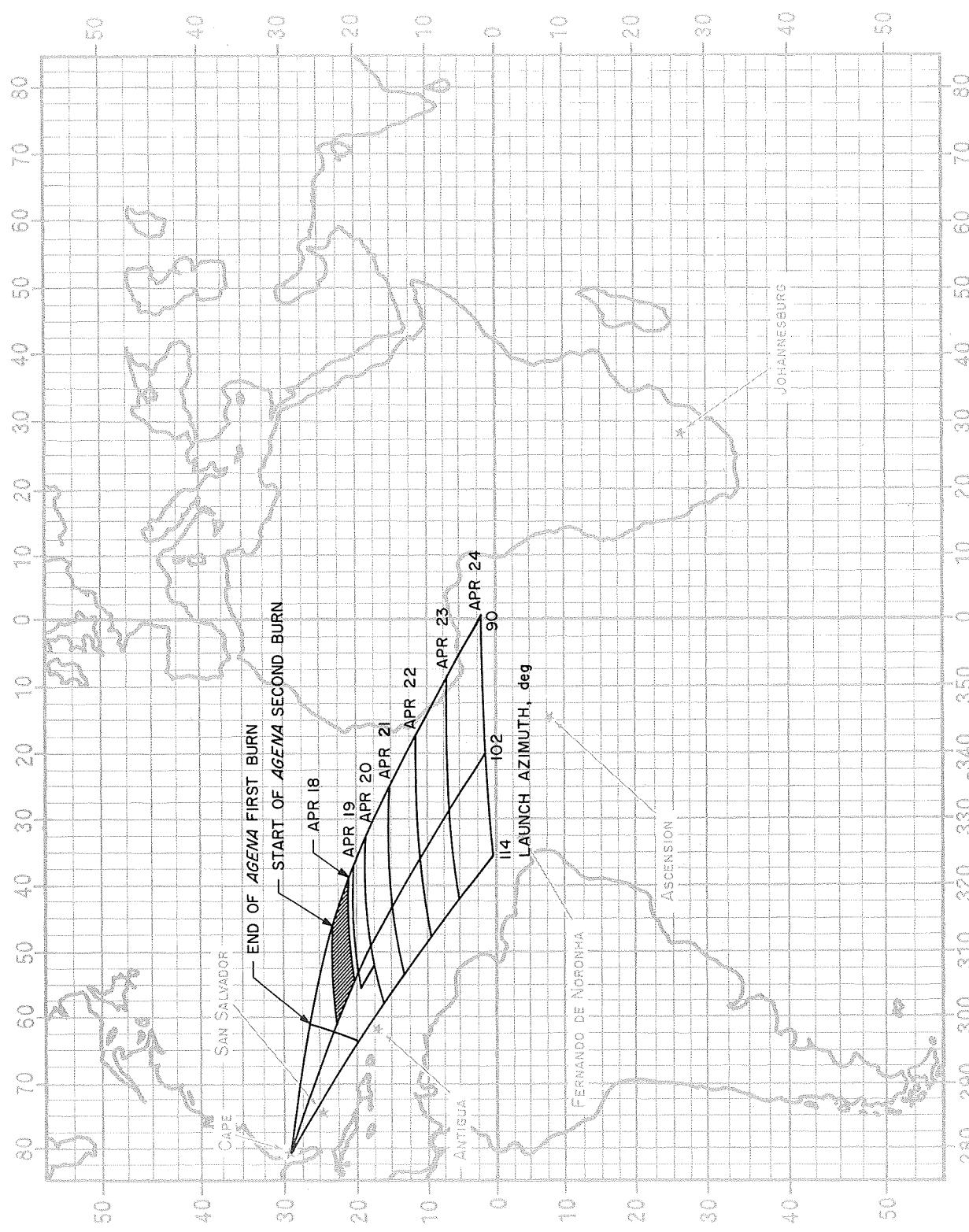


Fig. 9. Ranger injection for April 18 through April 24, 1965

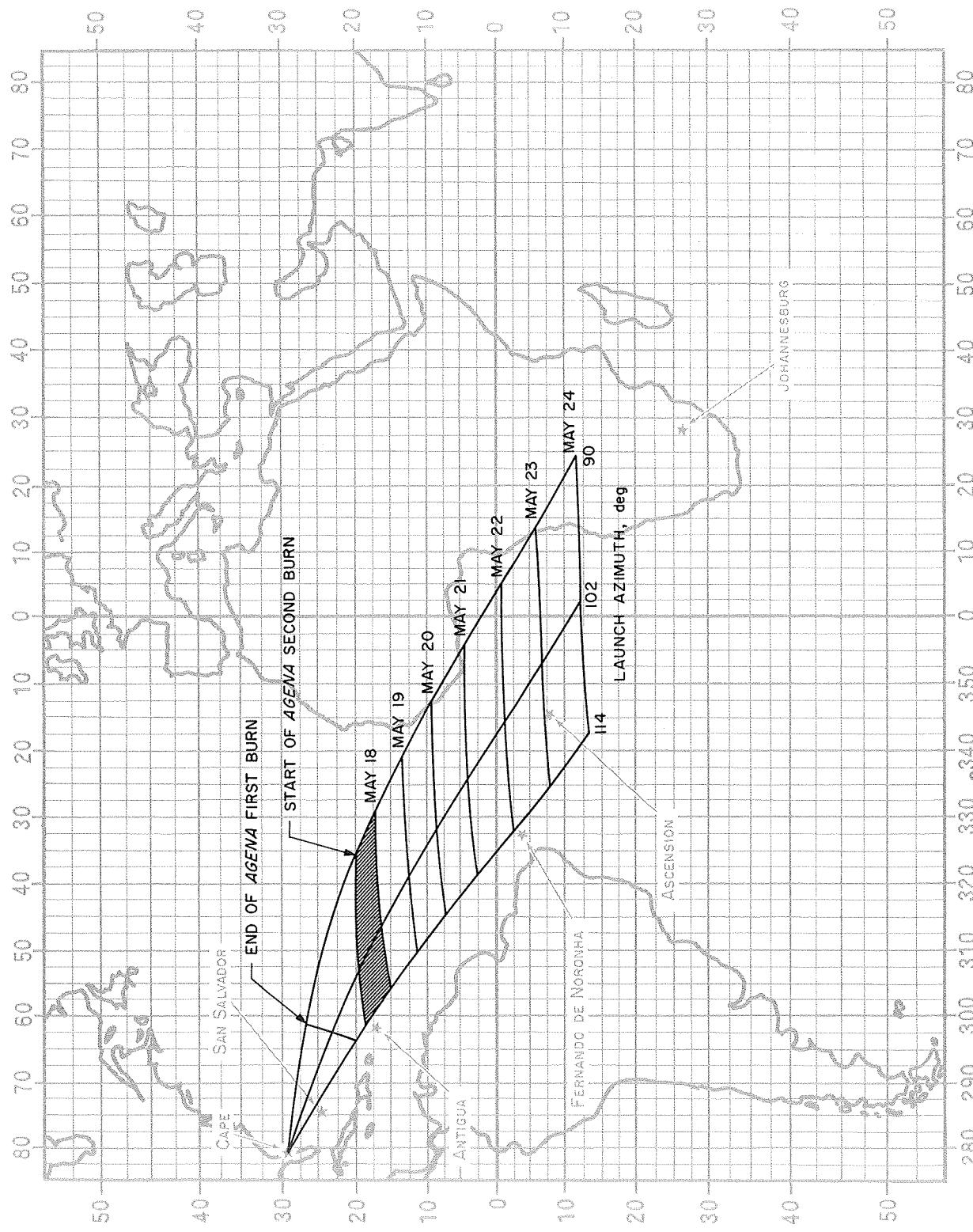


Fig. 10. Ranger injection loci for May 18 through May 24, 1965

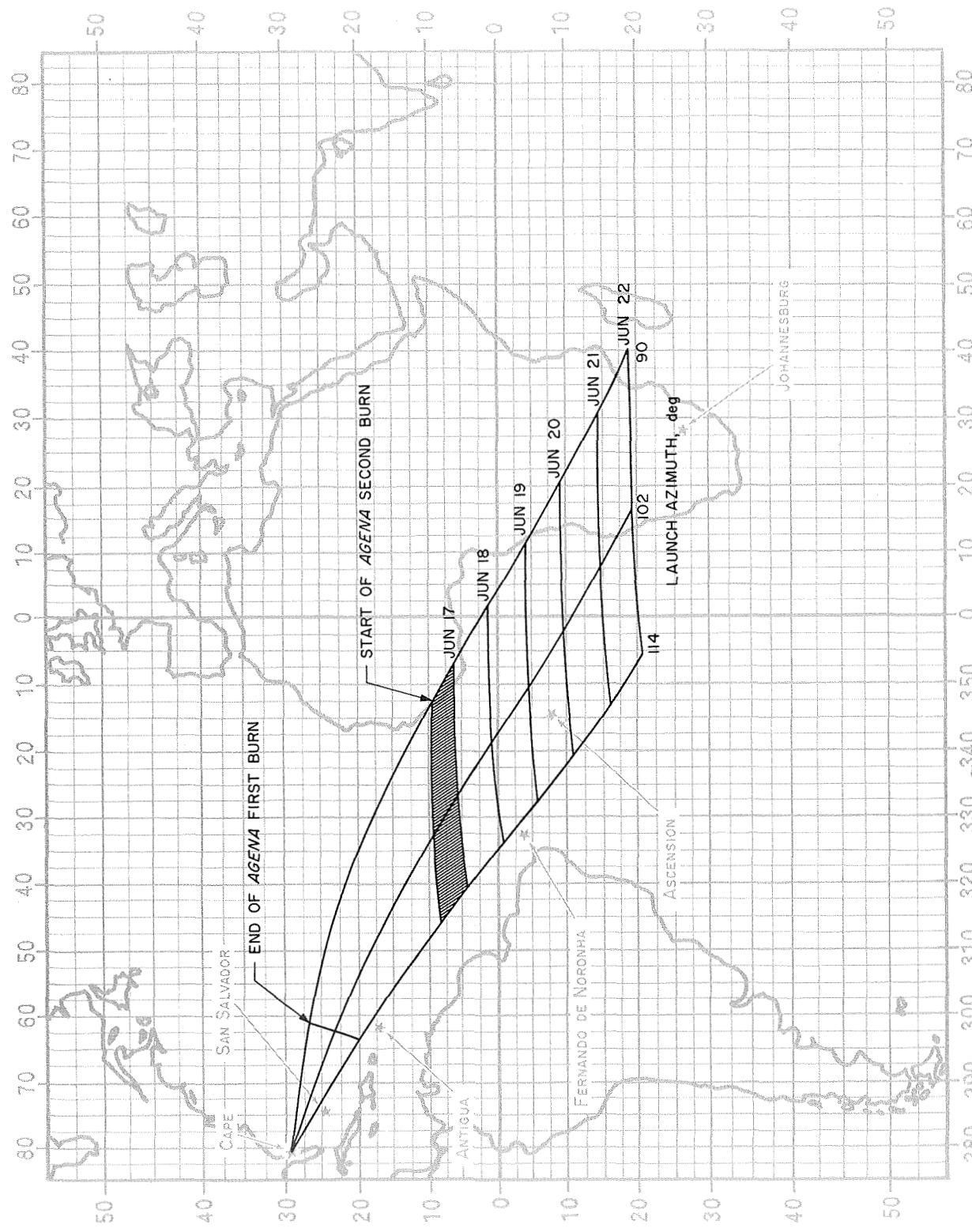


Fig. 11. Ranger injection loci for June 17 through June 22, 1965

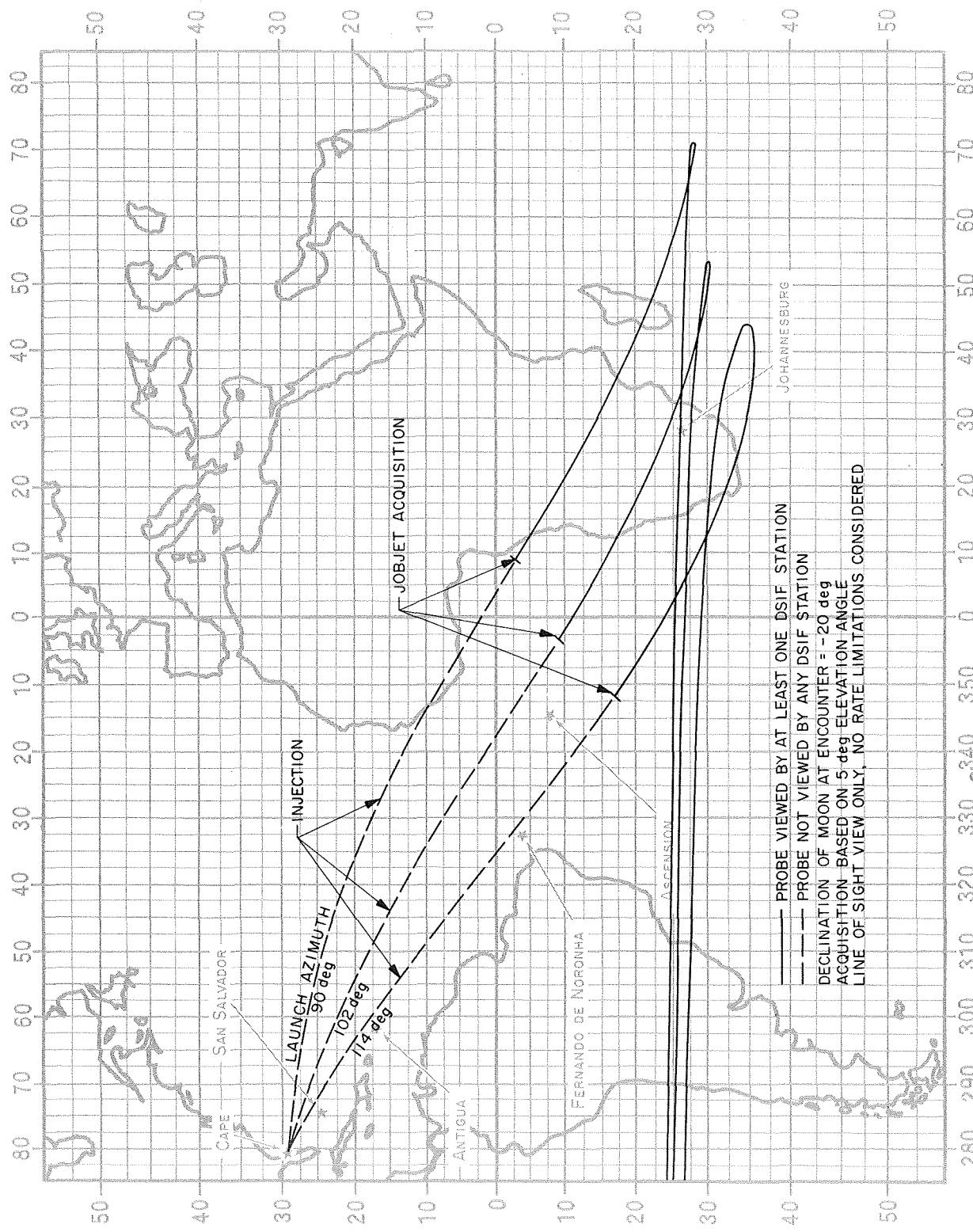


Fig. 12. Earth track for lunar declination at encounter of -20 deg

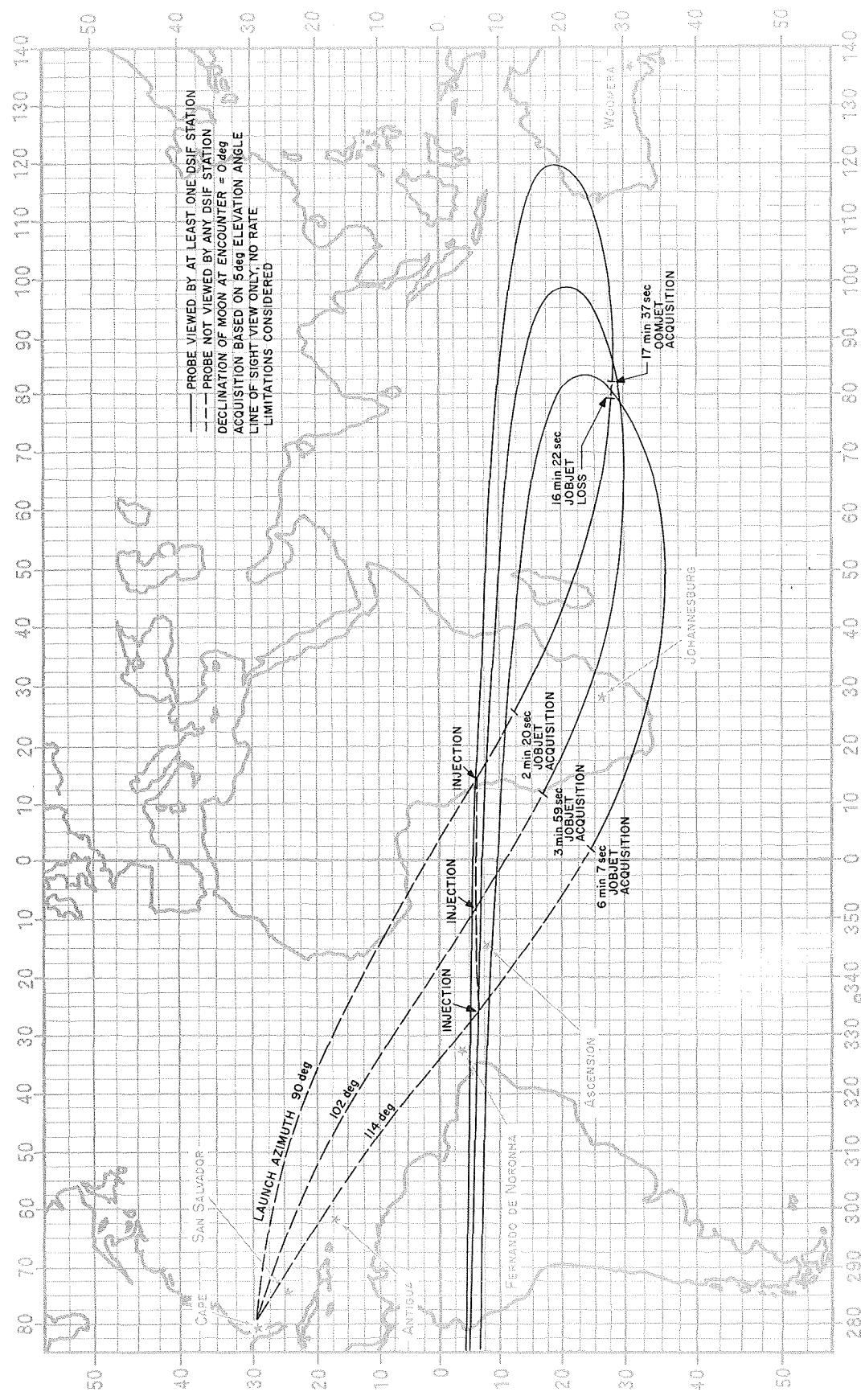


Fig. 13. Earth track for lunar declination at encounter of 0 deg

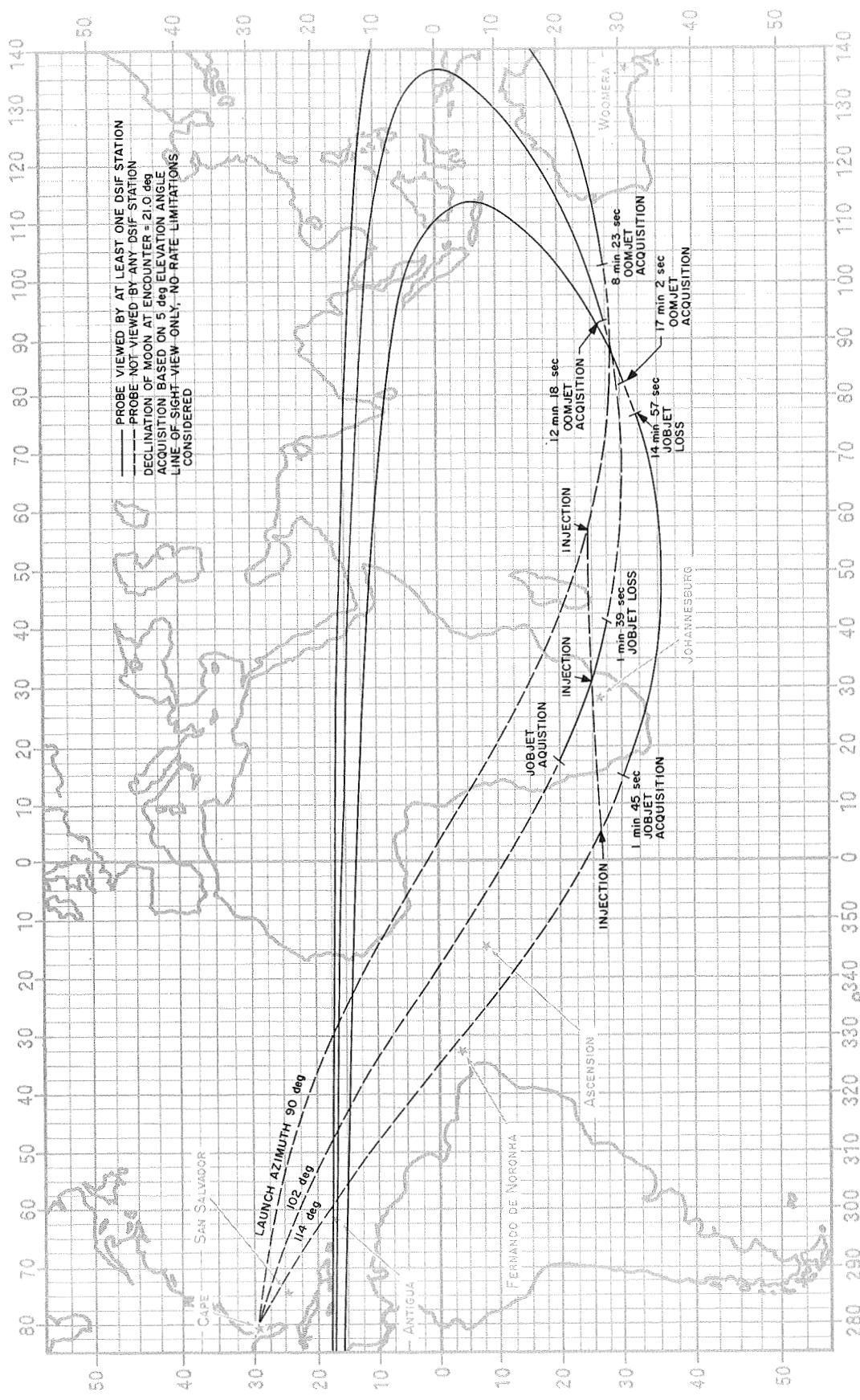


Fig. 14. Earth track for lunar declination at encounter 21 deg

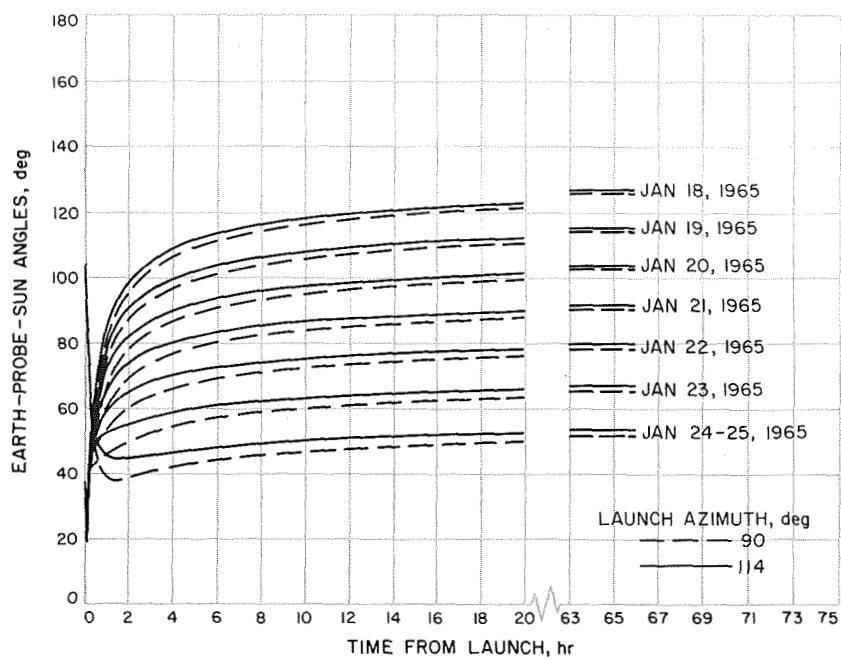


Fig. 15. E-P-S angle vs. time from launch for January launch period

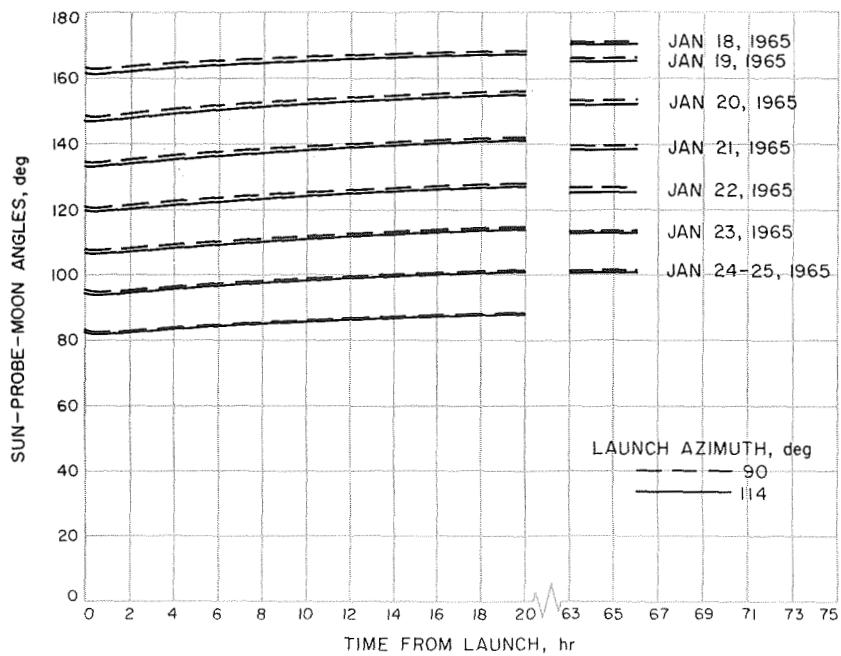


Fig. 16. S-P-M angle vs. time from launch for January launch period

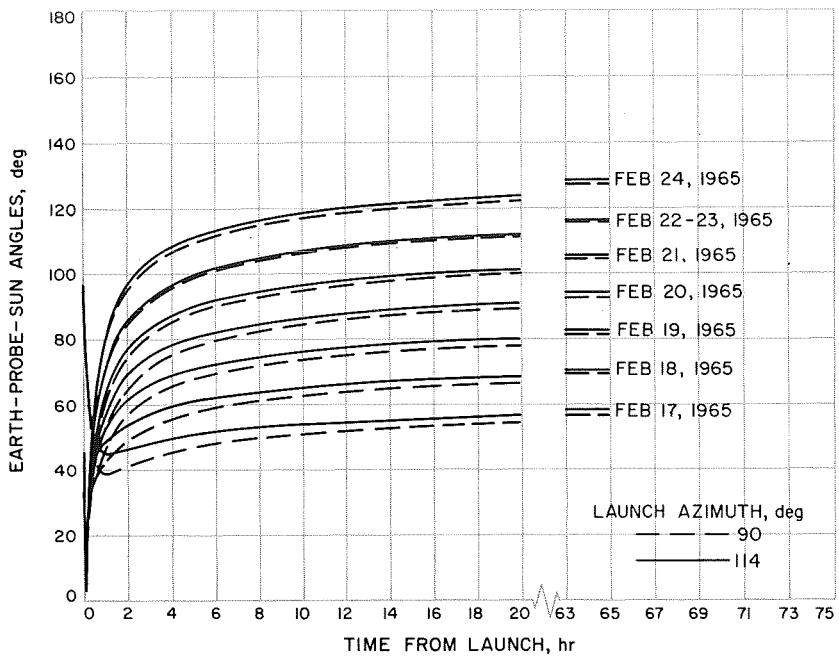


Fig. 17. E-P-S angle vs. time from launch for February launch period

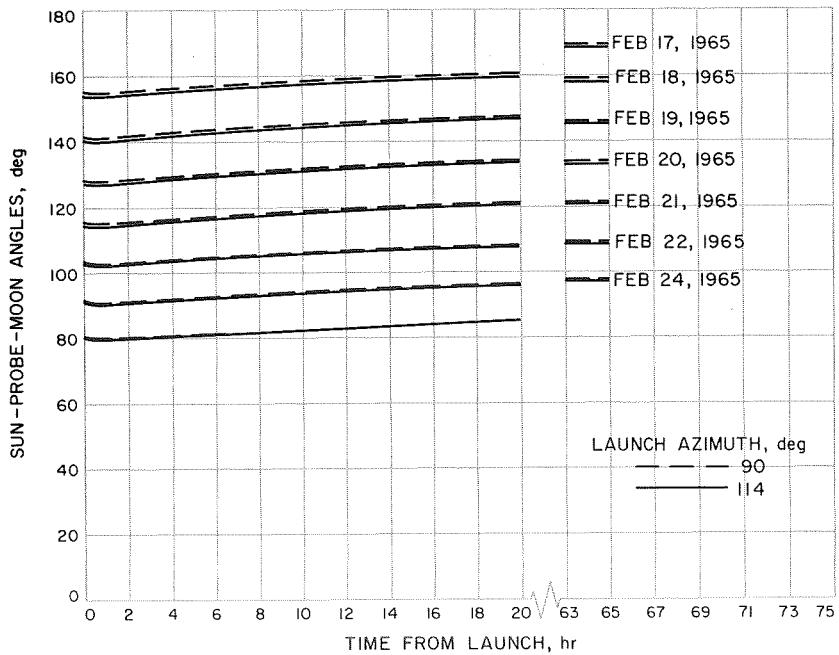


Fig. 18. S-P-M angle vs. time from launch February launch period

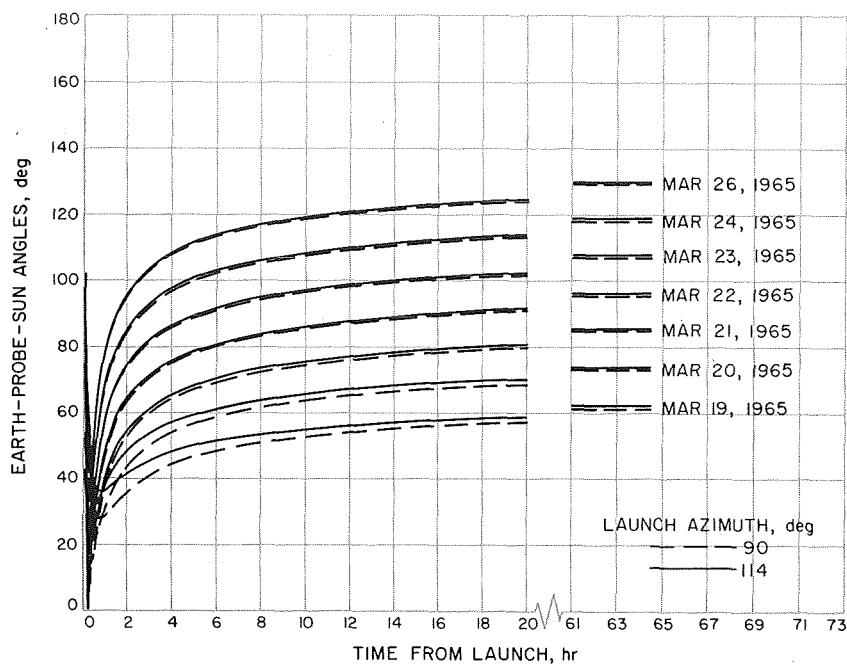


Fig. 19. E-P-S angle vs. time from launch for March launch period

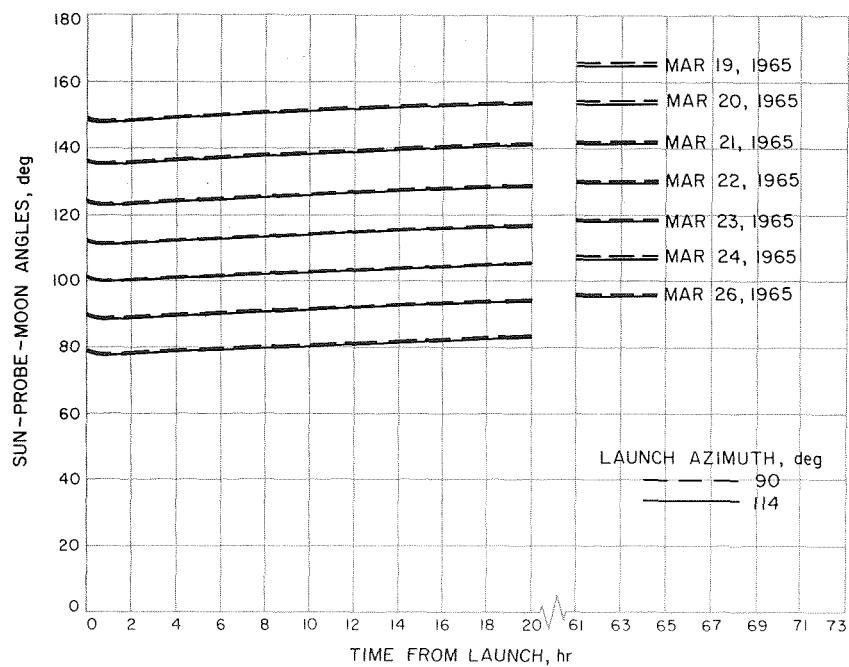


Fig. 20. S-P-M angle vs. time from launch for March launch period

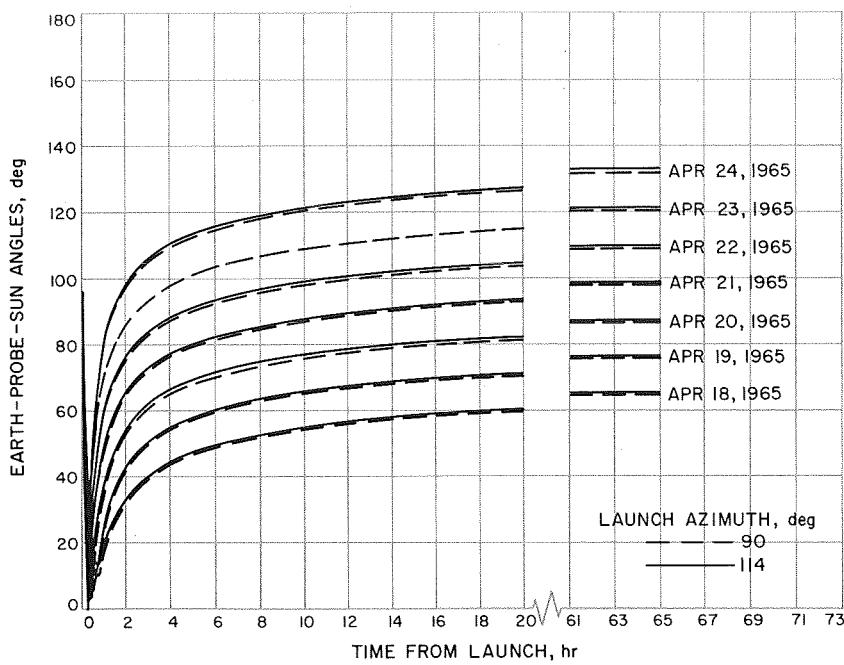


Fig. 21. E-P-S angle vs. time from launch for April launch period

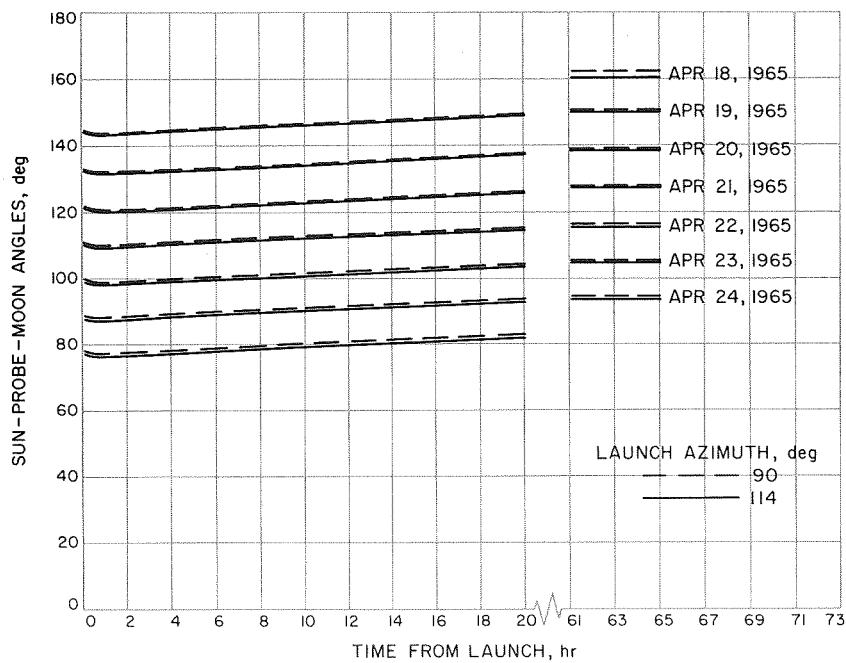


Fig. 22. S-P-M angle vs. time from launch for April launch period

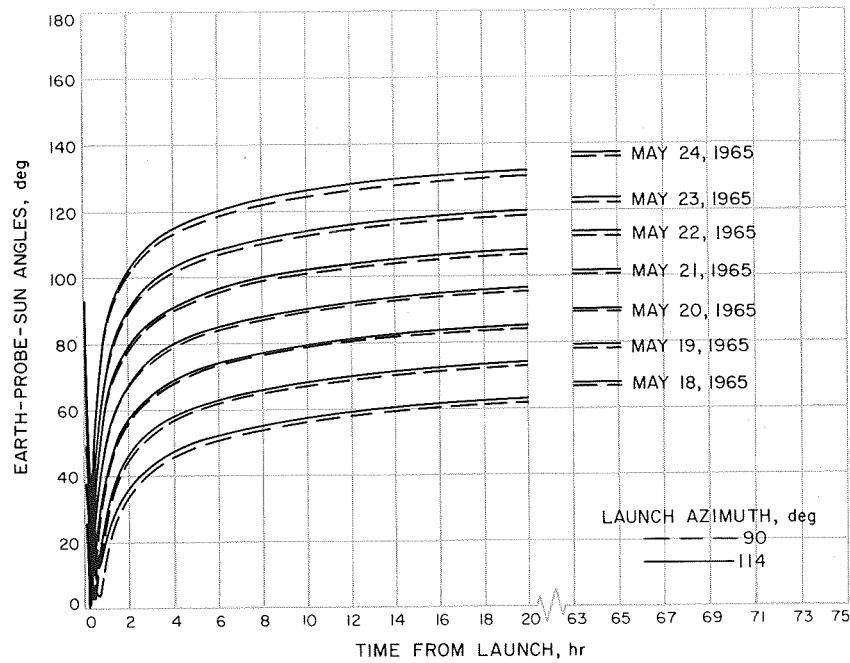


Fig. 23. E-P-S angle vs. time from launch for May launch period

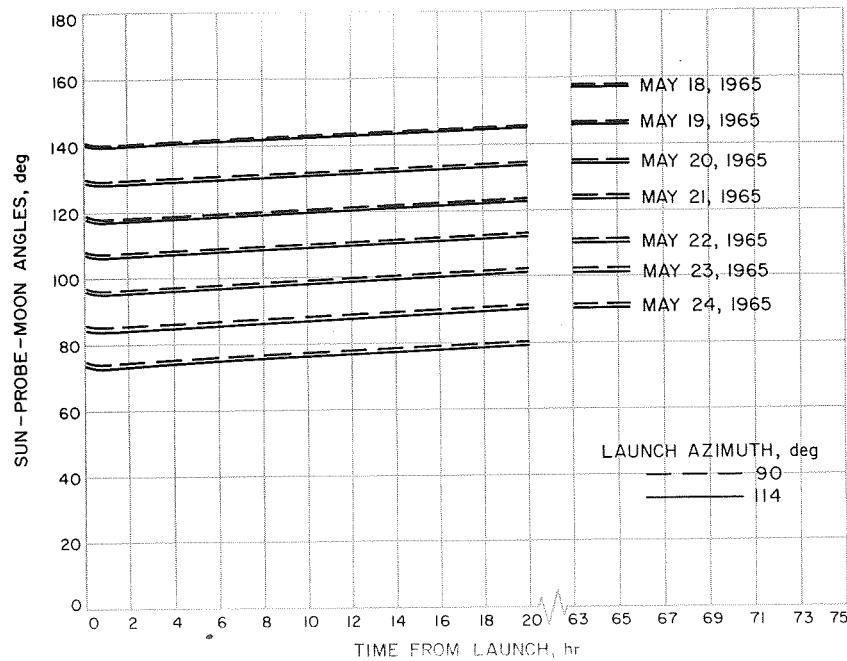


Fig. 24. S-P-M angle vs. time from launch for May launch period

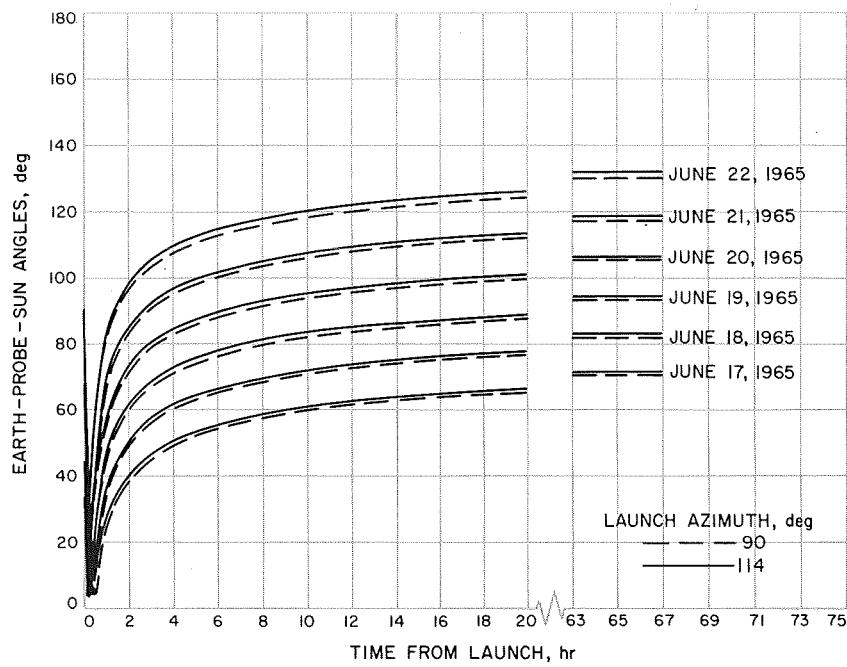


Fig. 25. E-P-S angle vs. time from launch for June launch period

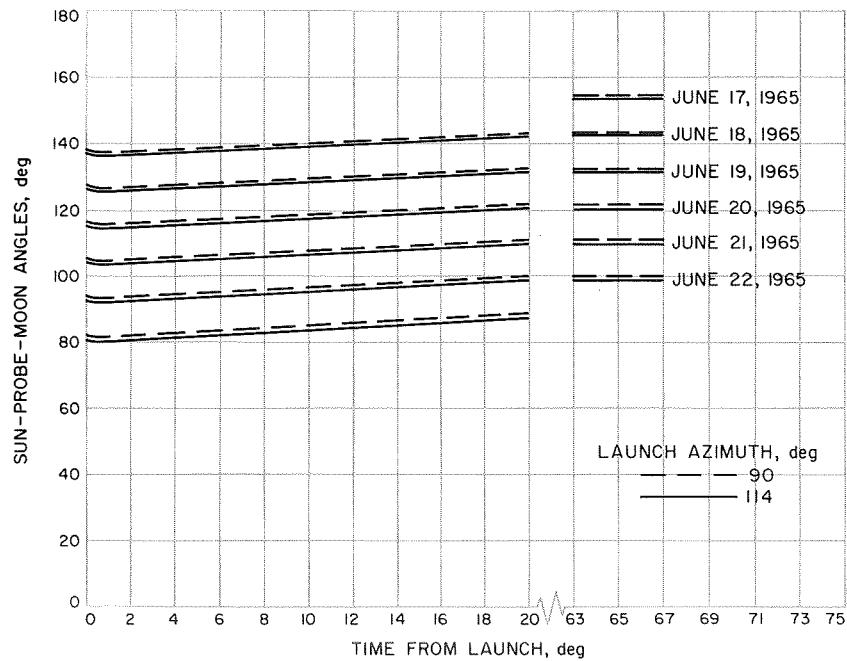


Fig. 26. S-P-M angle vs. time from launch for June launch period

PD-19 Ranger Block III

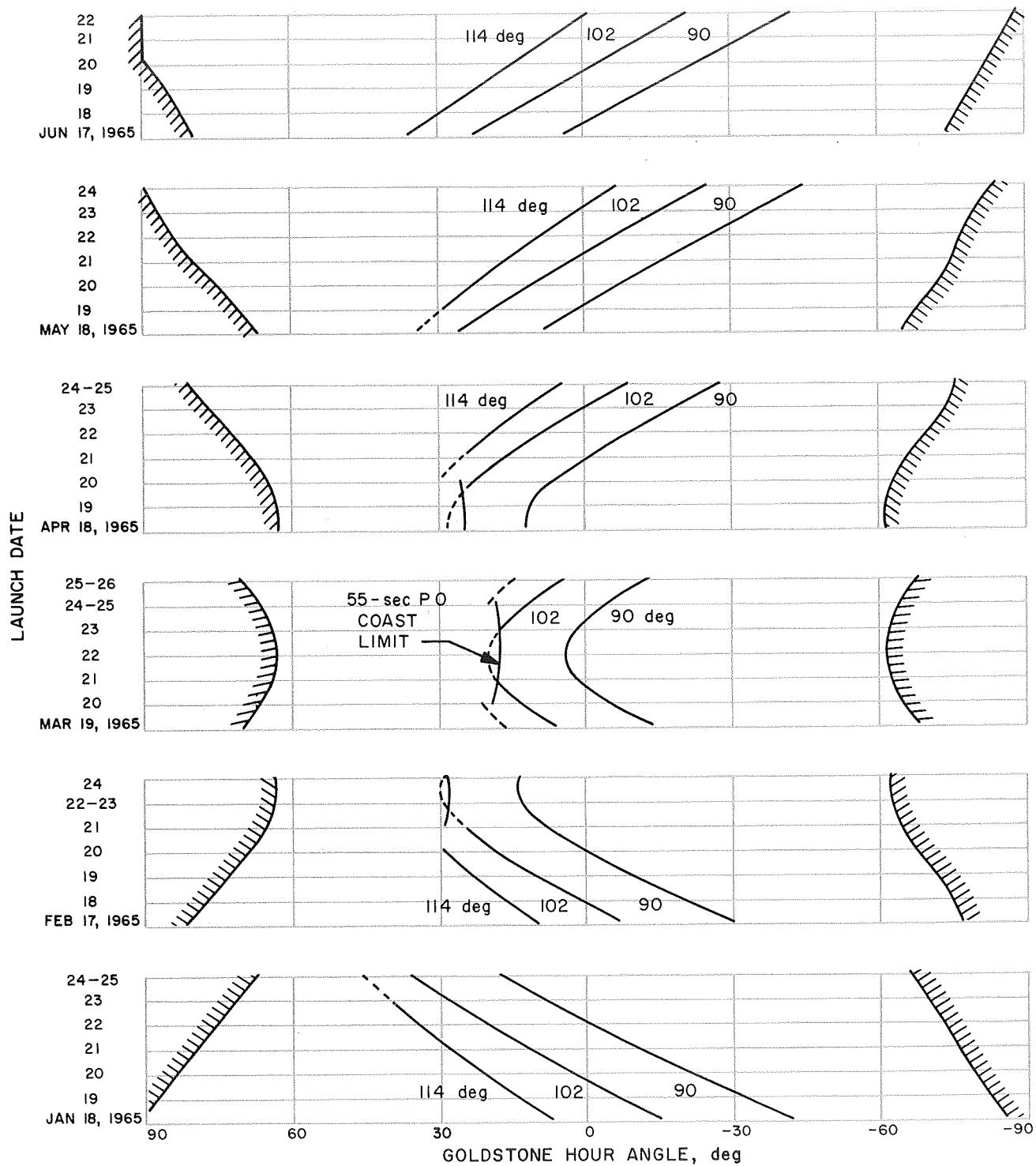
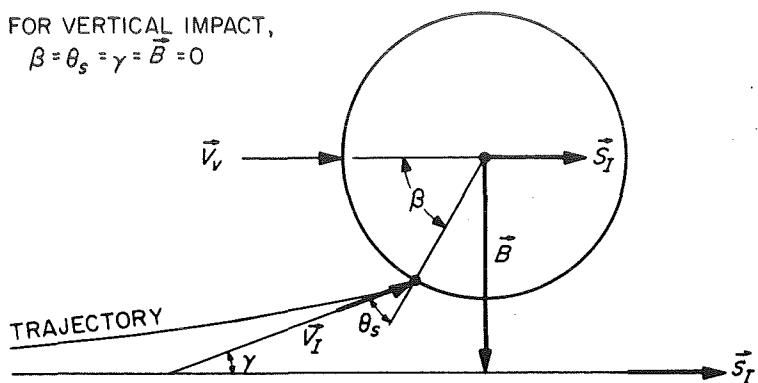


Fig. 27. Goldstone viewing at lunar impact

FOR VERTICAL IMPACT,  
 $\beta = \theta_s = \gamma = \bar{B} = 0$



$\beta$  = BIAS ANGLE

$\theta_s$  = ANGLE BETWEEN IMPACT VELOCITY VECTOR AND LOCAL VERTICAL

$\gamma$  = ANGLE BETWEEN IMPACT VELOCITY VECTOR AND INCOMING ASYMPTOTE

$\vec{s}_I$  = INCOMING ASYMPTOTE DIRECTION

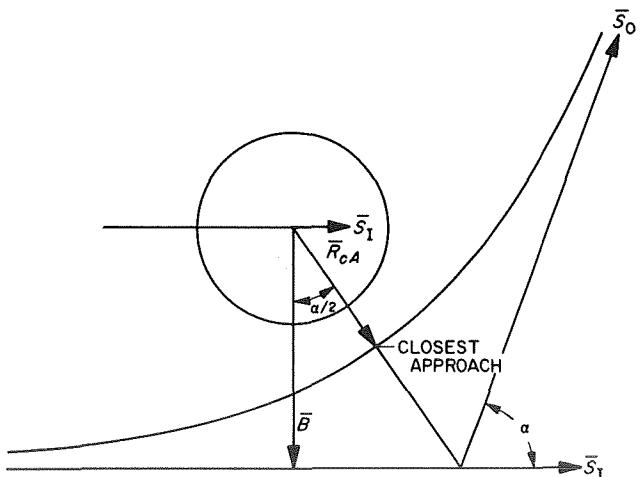
$\vec{B}$  = MISS PARAMETER

$\vec{V}_I$  = IMPACT VELOCITY VECTOR

$\vec{V}_v$  = IMPACT VELOCITY VECTOR FOR VERTICAL IMPACT

Fig. 28. Definition of impact parameters

Fig. 29. Definition of flyby parameters



$\bar{R}_{cA}$  ~ SELENOCENTRIC DISTANCE TO PROBE AT CLOSEST APPROACH

$\bar{B}$  ~ MISS PARAMETER

$\vec{s}_I$  ~ INCOMING ASYMPTOTE DIRECTION

$\vec{s}_0$  ~ OUTGOING ASYMPTOTE DIRECTION

$\alpha$  ~ ANGLE BETWEEN  $s_I$  AND  $s_0$ , DEFLECTION ANGLE

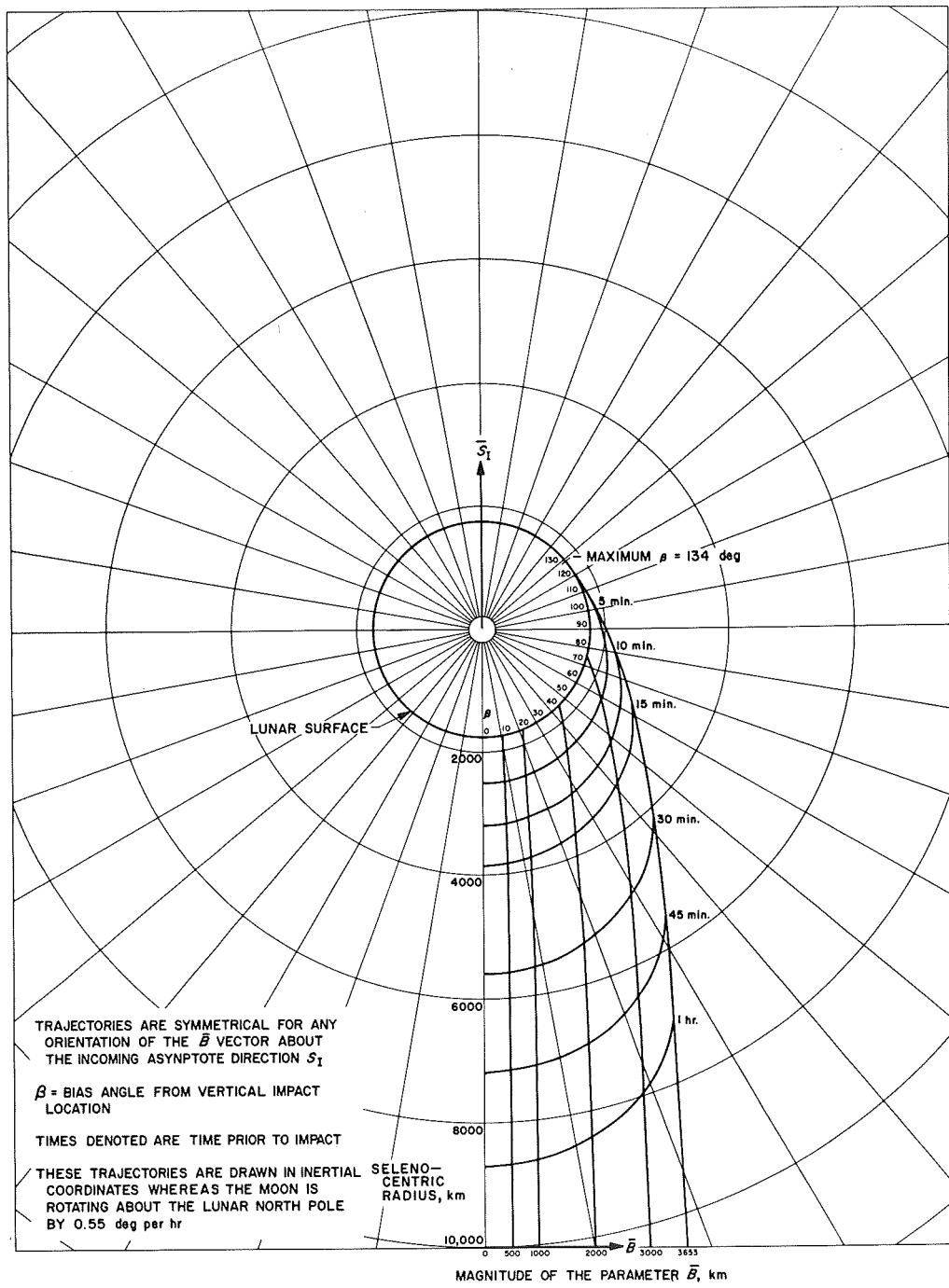


Fig. 30. Impact trajectories for the hour prior to lunar impact,  $V_I = 2.6 \text{ km/sec}$

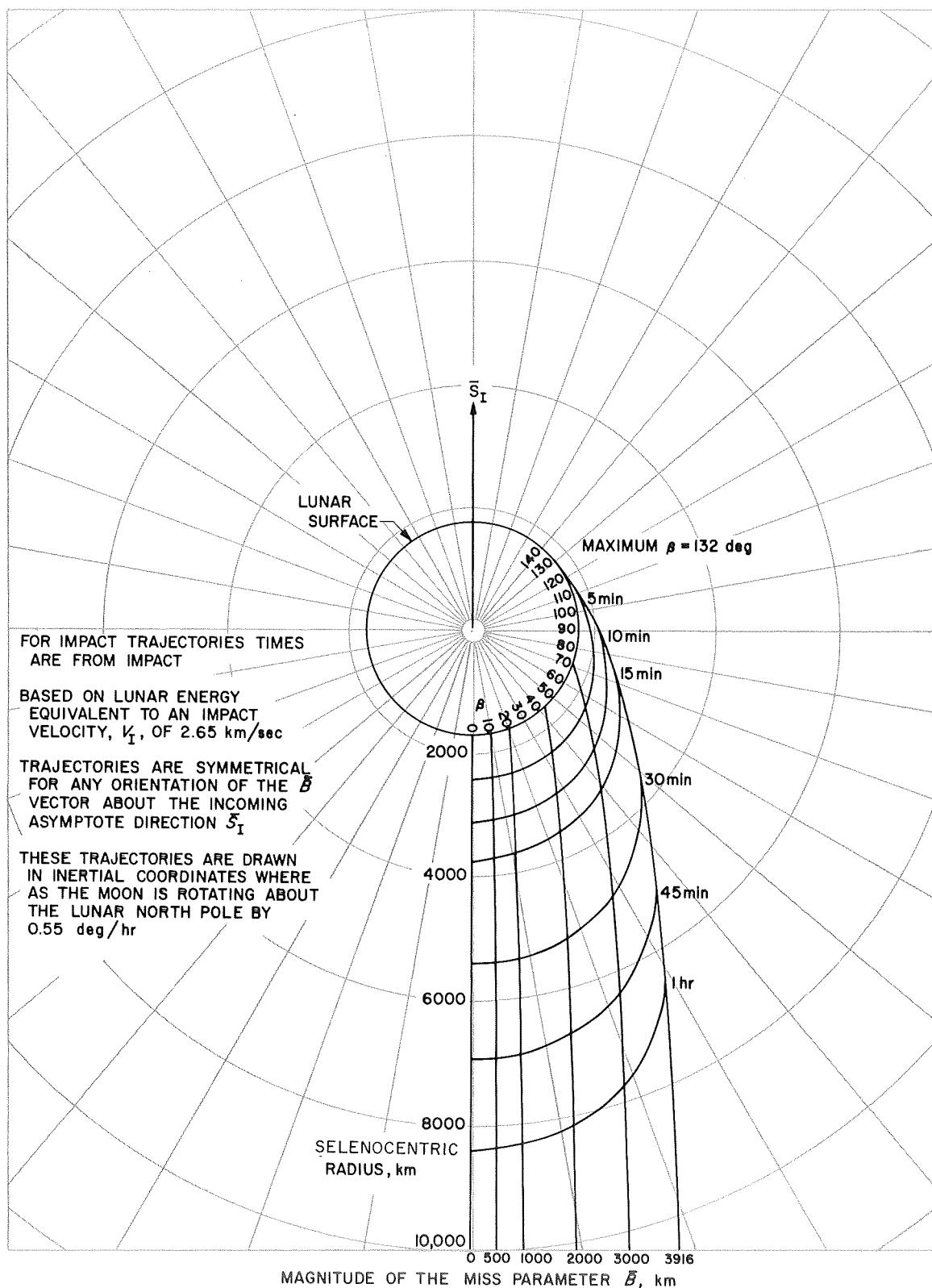


Fig. 31. Impact trajectories for the hour prior to lunar impact,  $V_I = 2.65$  km/sec

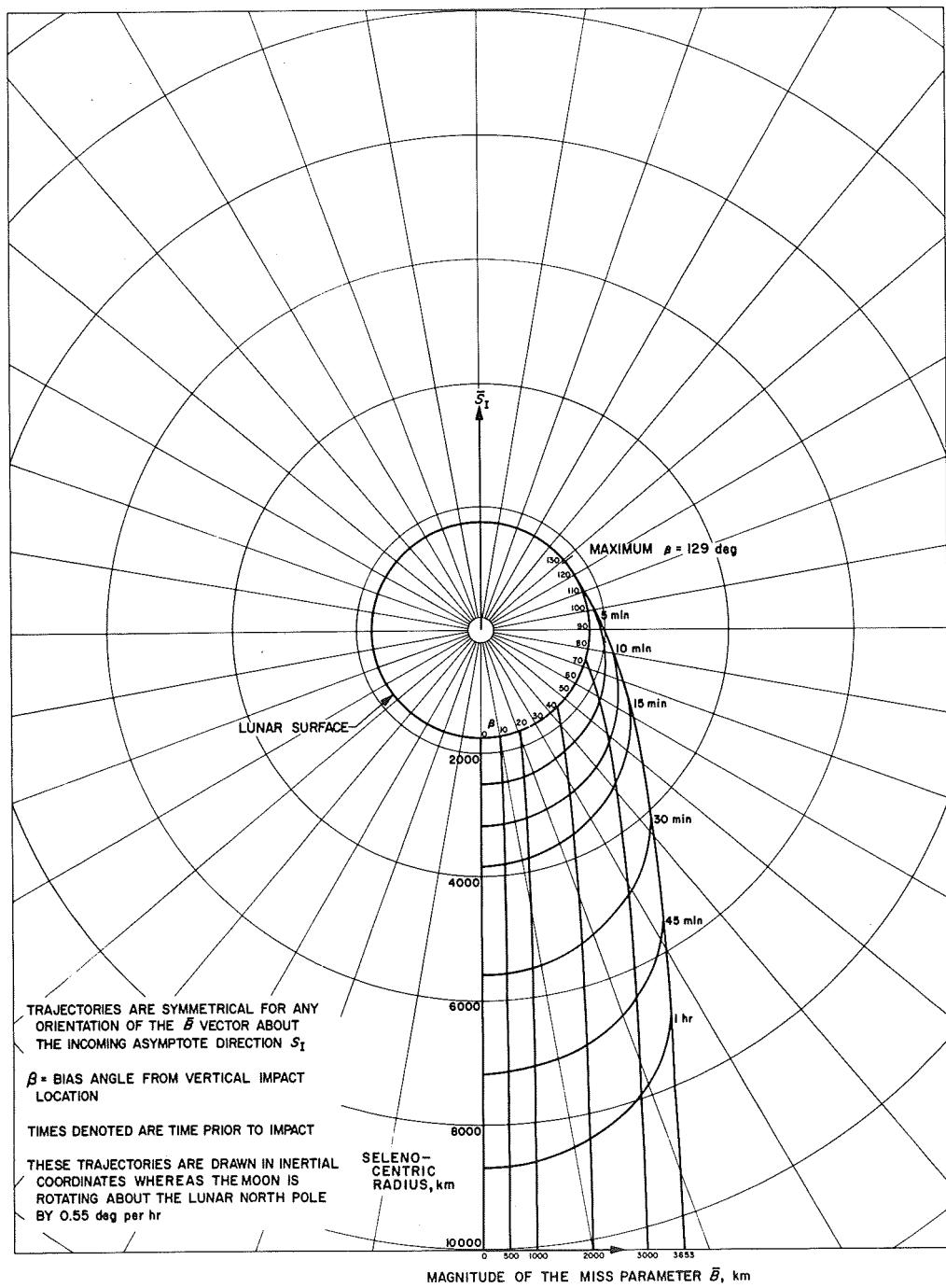


Fig. 32. Impact trajectories for the hour prior to lunar impact,  $V_I = 2.7$  km/sec

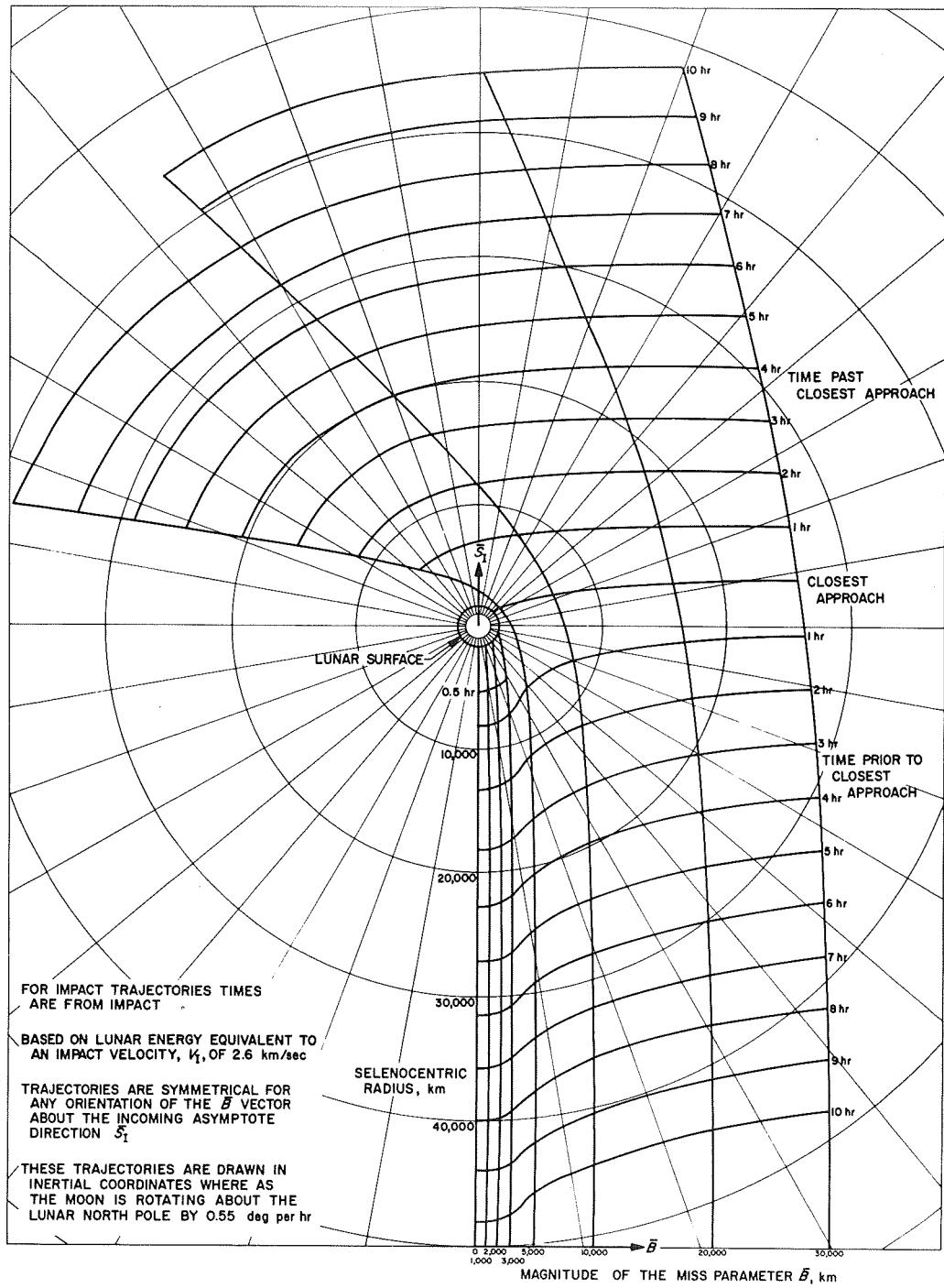


Fig. 33. Trajectories during the 10 hr prior to and beyond lunar encounter,  $V_I = 2.6$  km/sec

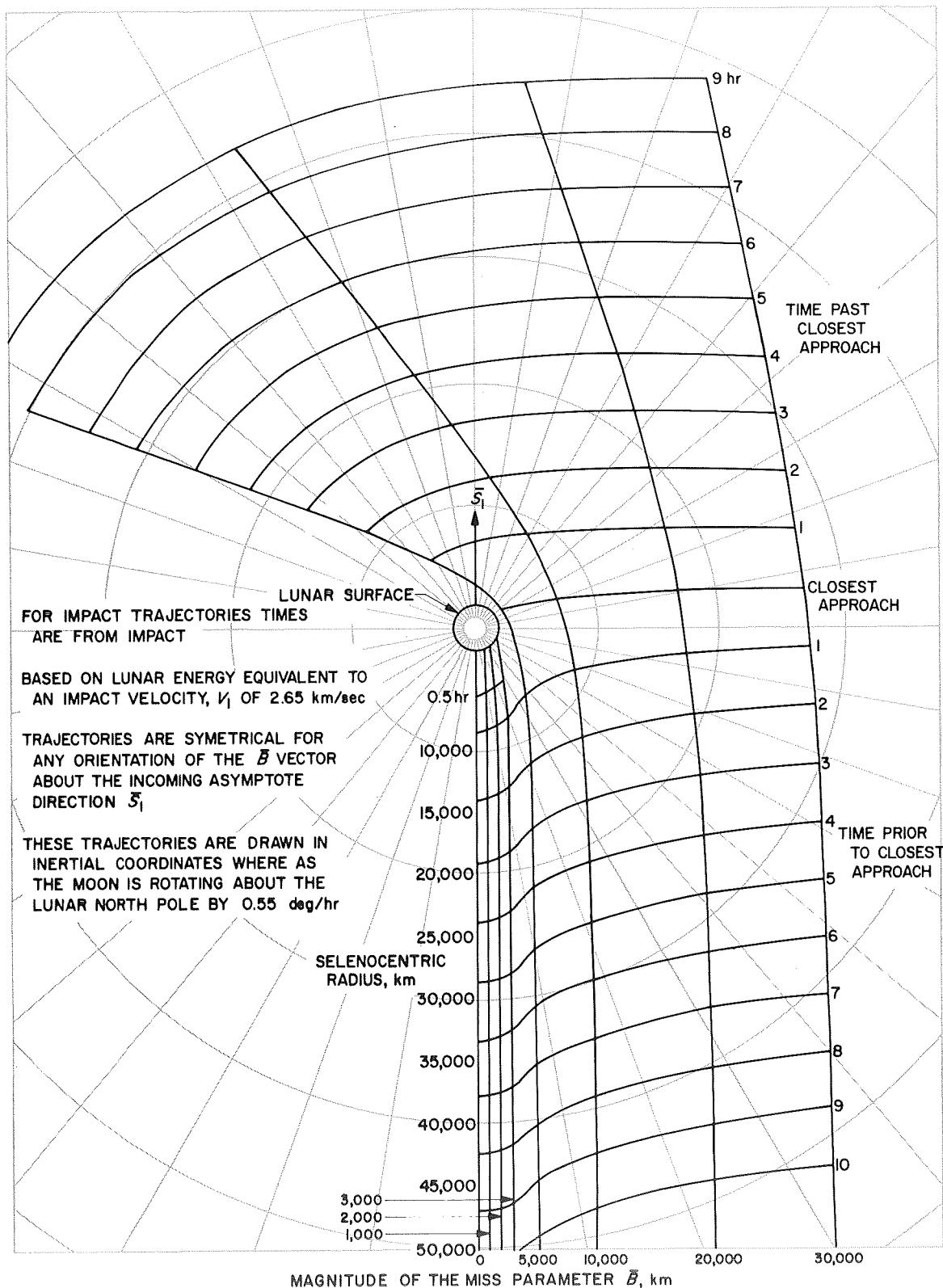


Fig. 34. Trajectories during the 10 hr prior to and beyond lunar encounter,  $V_I = 2.65$  km/sec

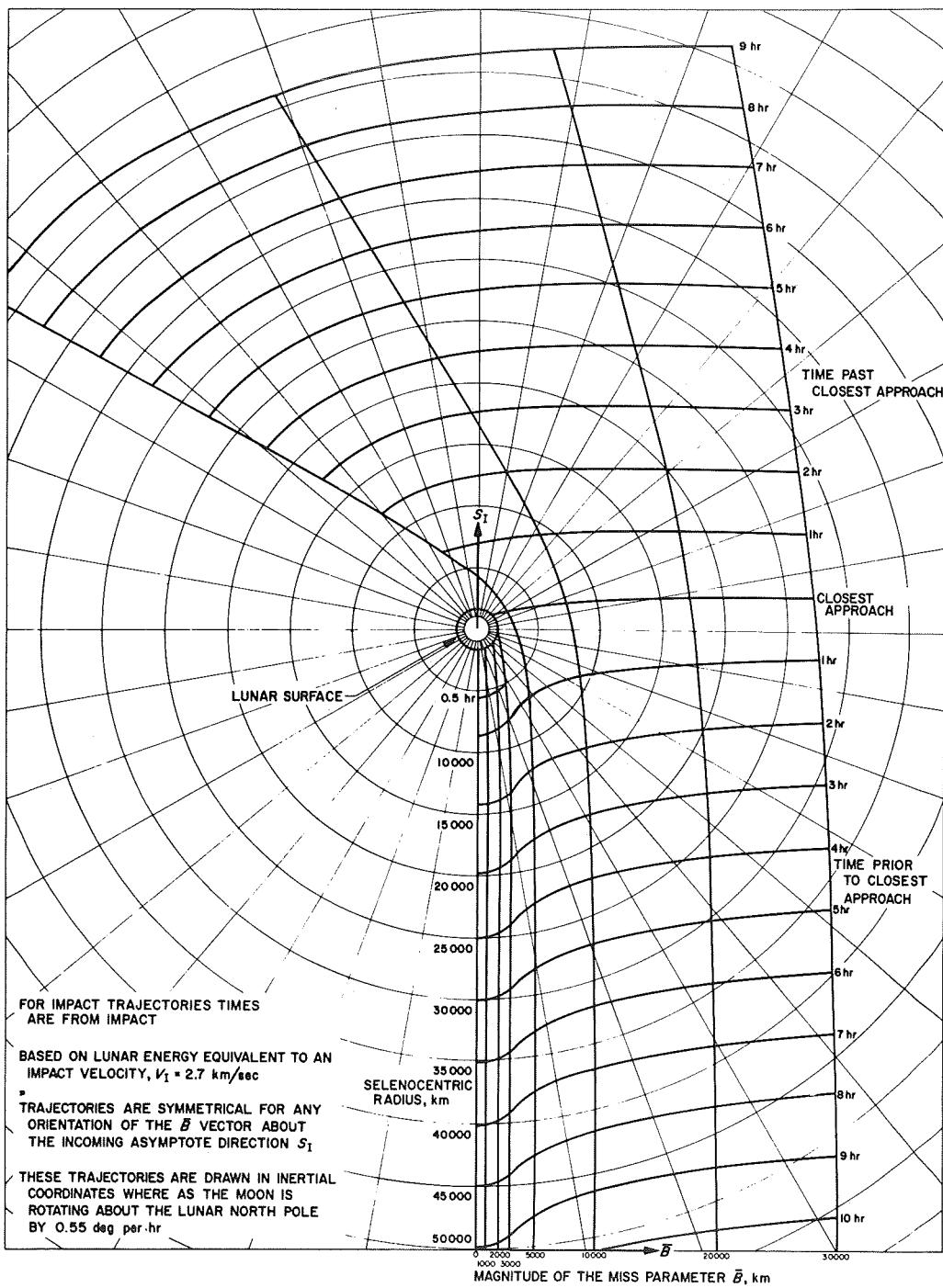


Fig. 35. Trajectories during the 10 hr prior to and beyond lunar encounter,  $V_I = 2.7 \text{ km/sec}$

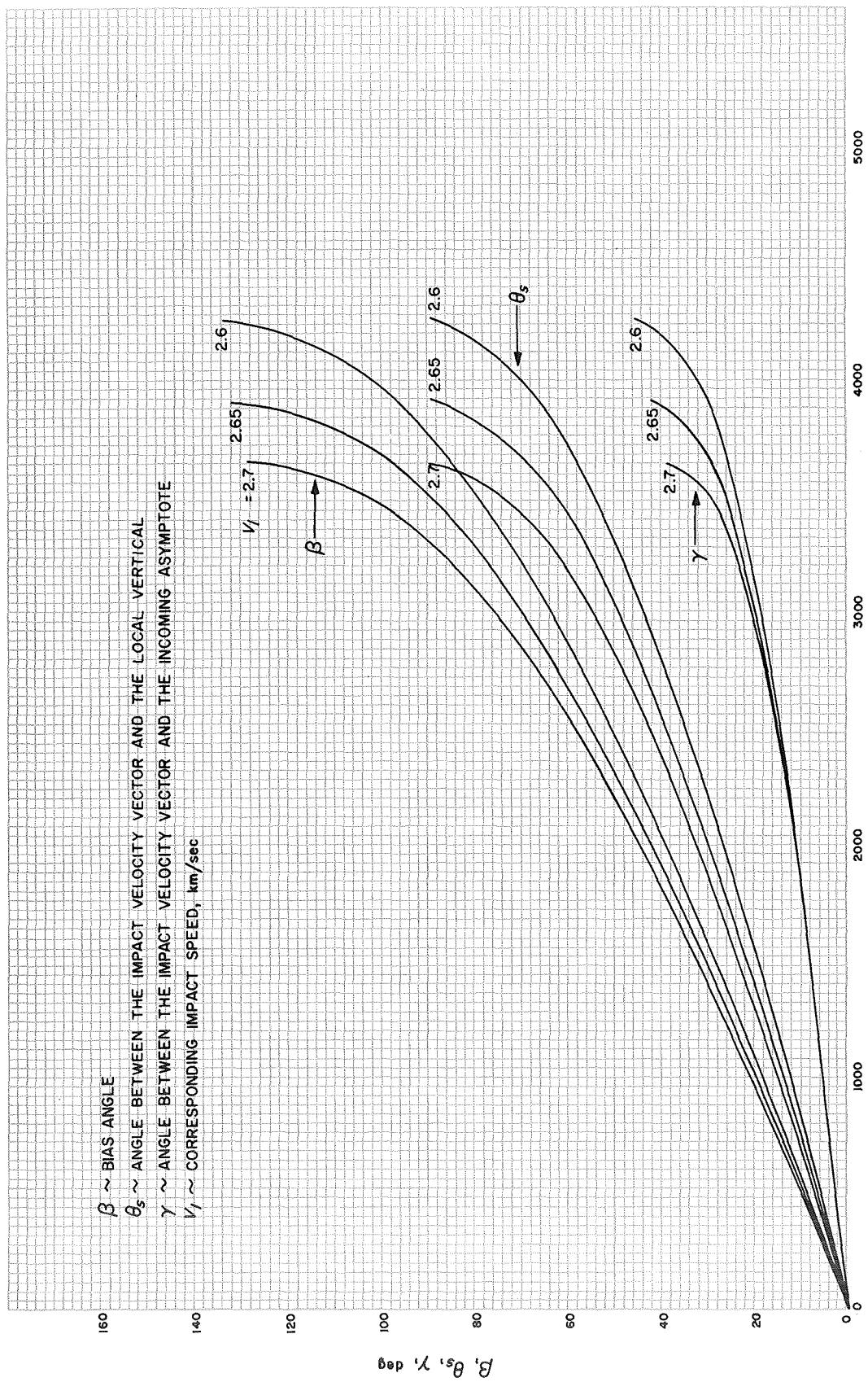
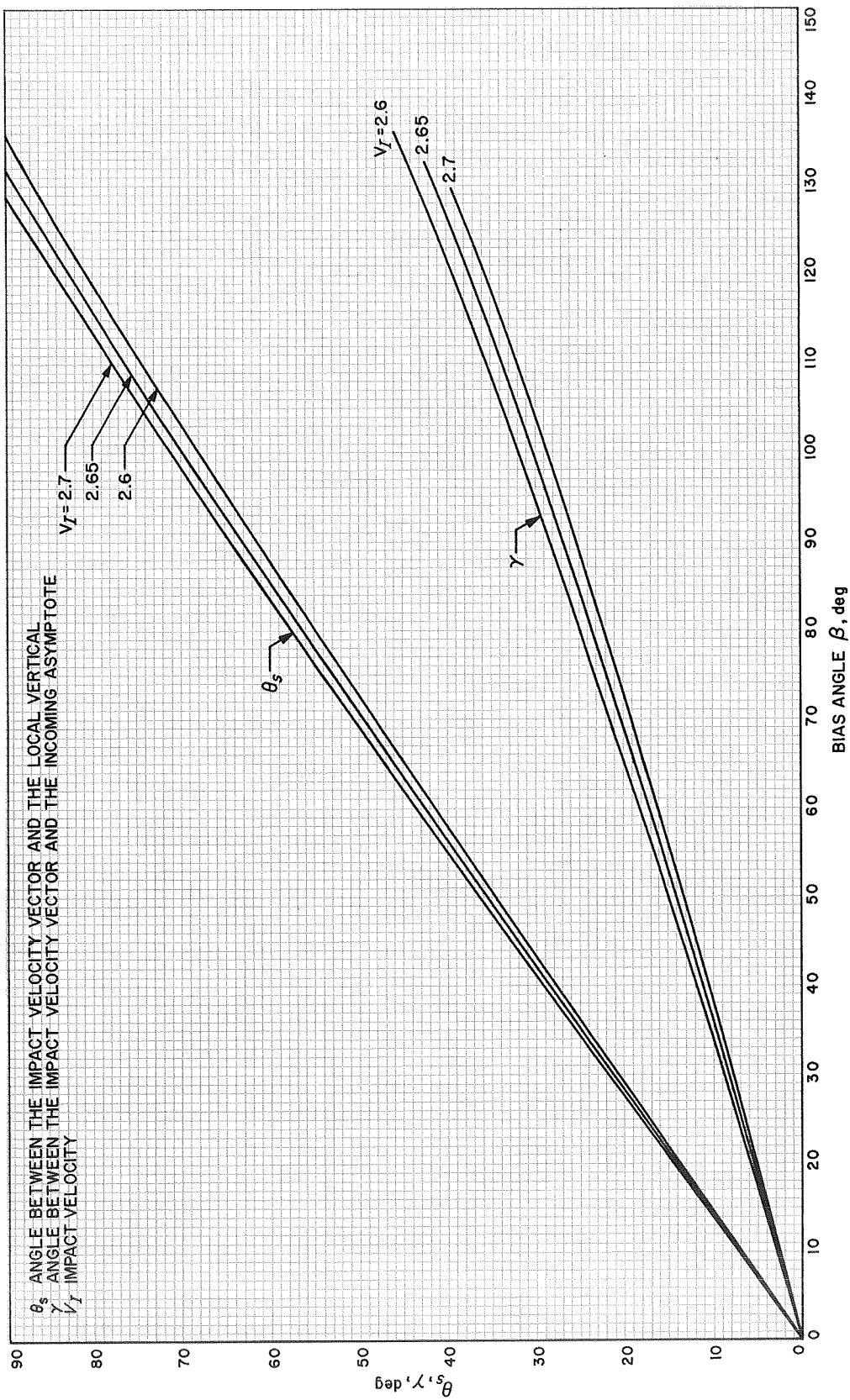


Fig. 36. Magnitude of the miss parameter B

Fig. 37. Impact parameters vs. the bias angle  $\beta$

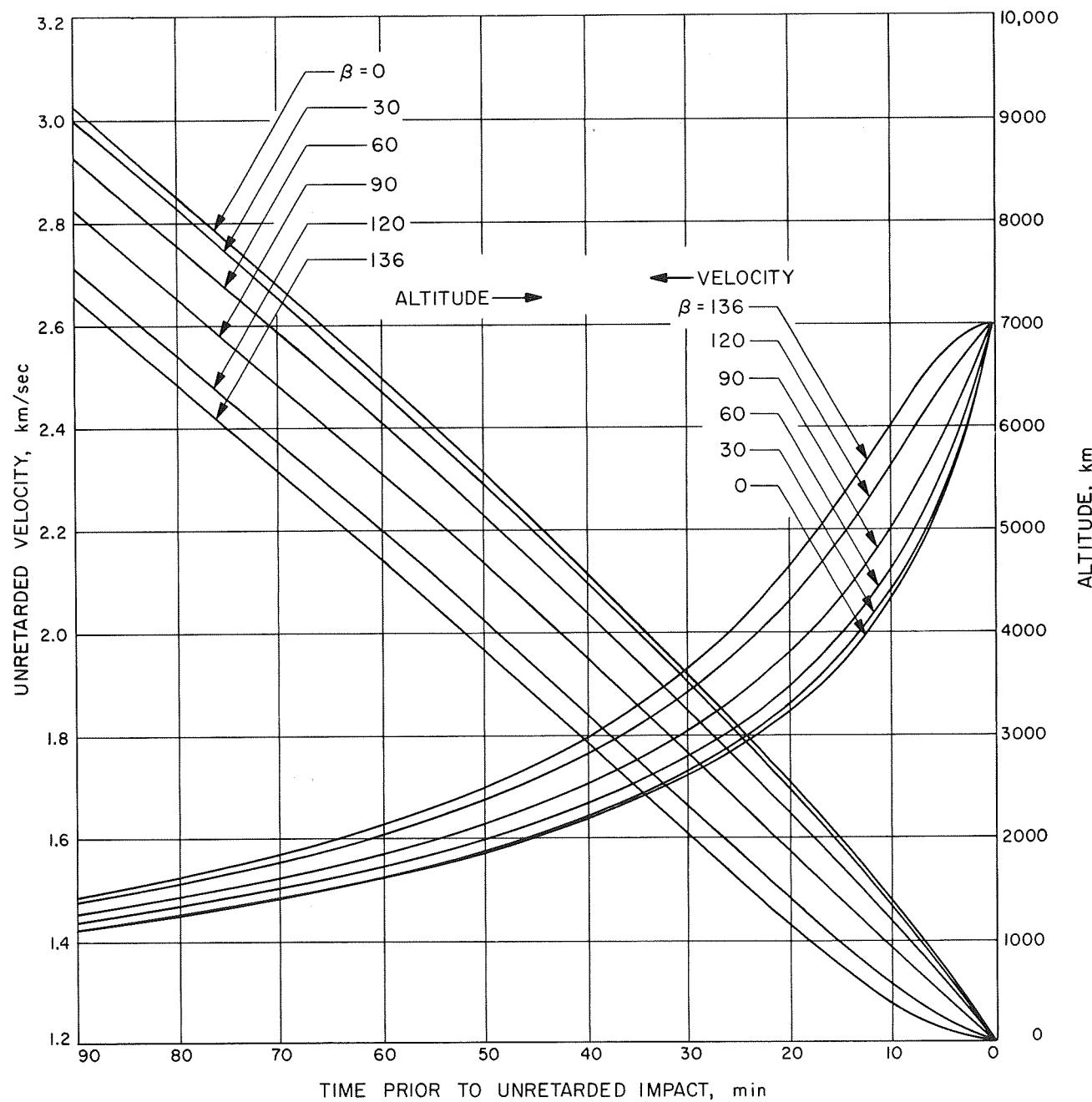


Fig. 38. Velocity and altitude vs. time from lunar impact,  $V_I = 2.6$  km/sec

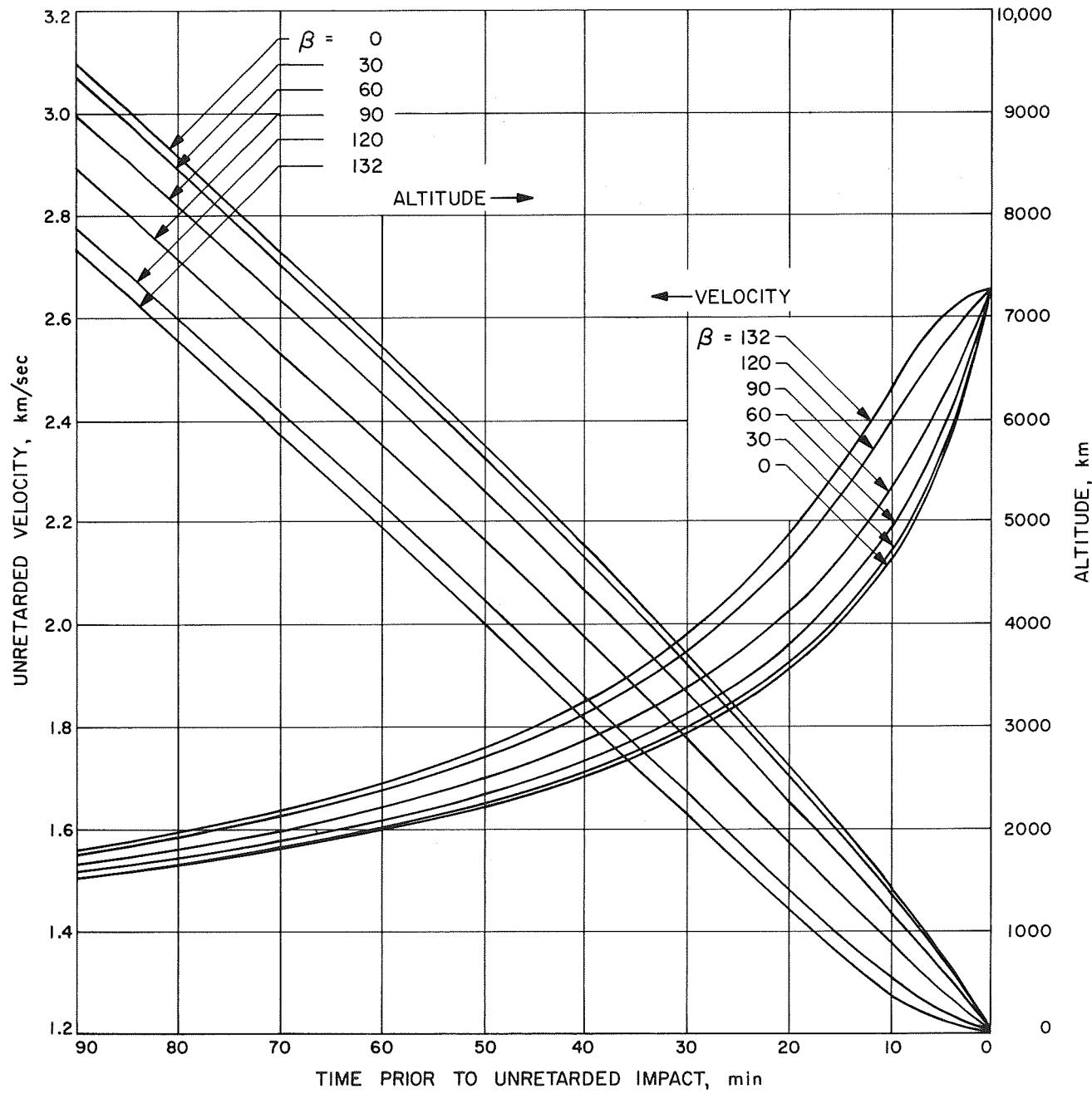


Fig. 39. Velocity and altitude vs. time from lunar impact,  $V_I = 2.65$  km/sec

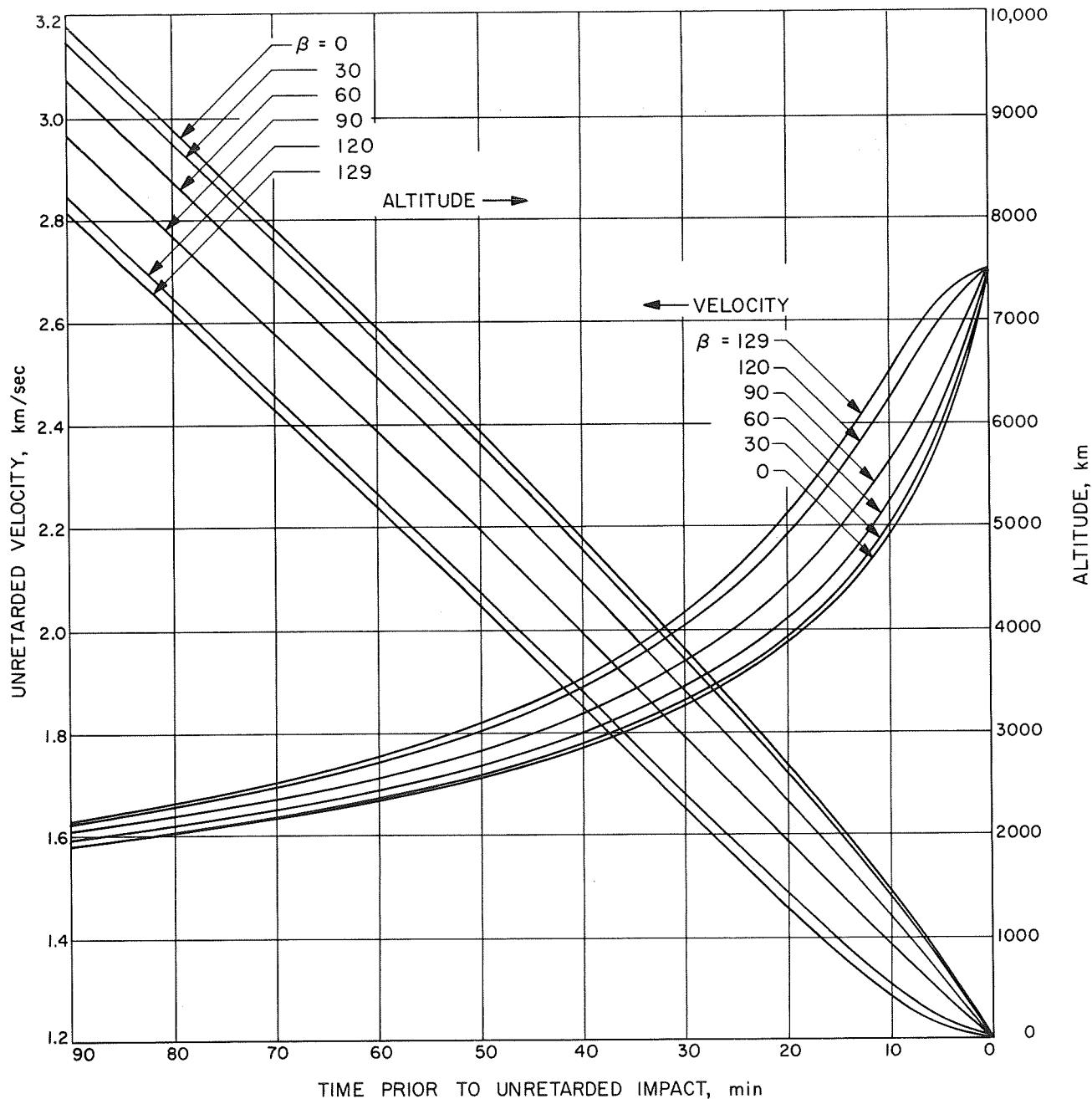
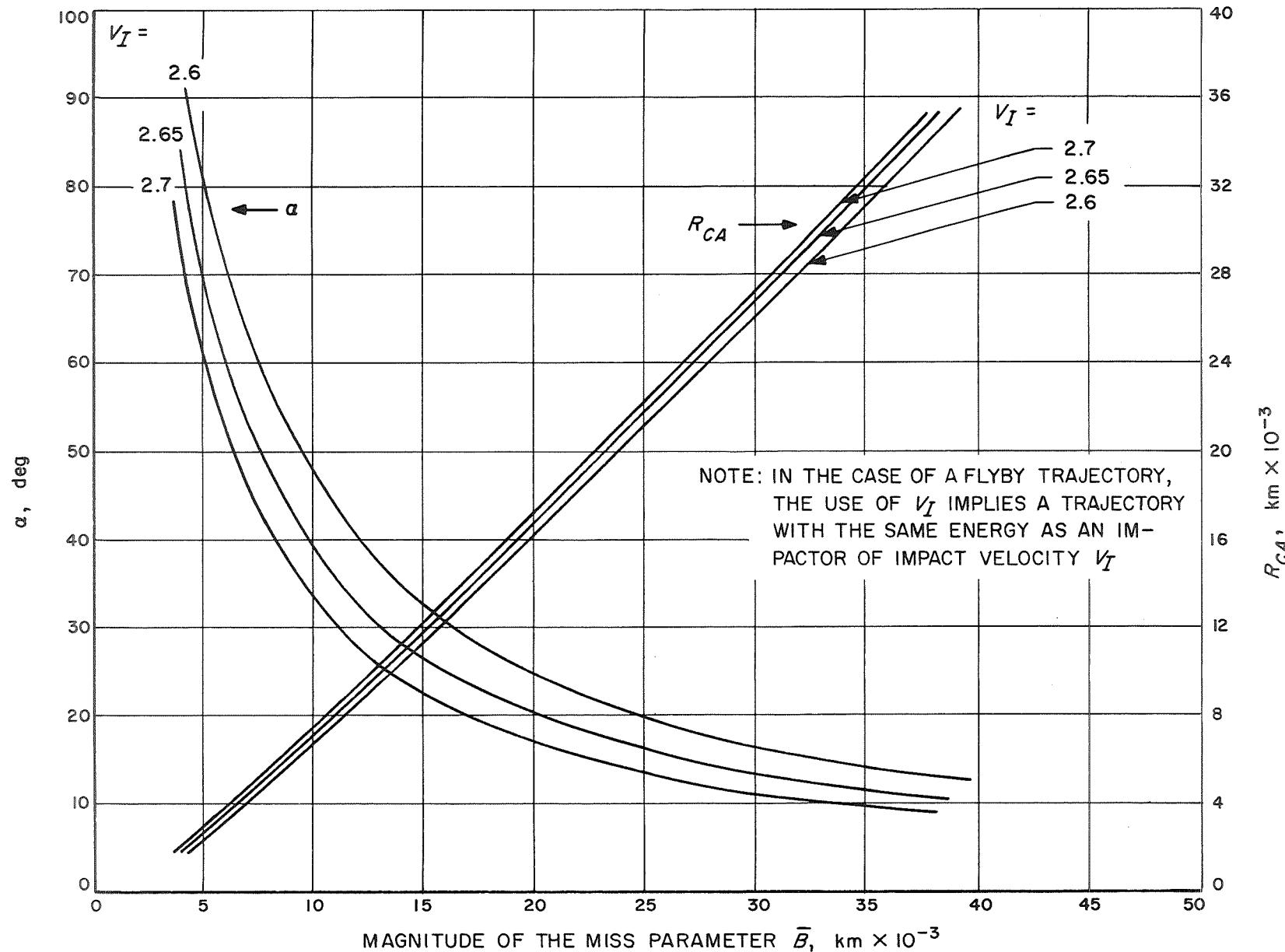
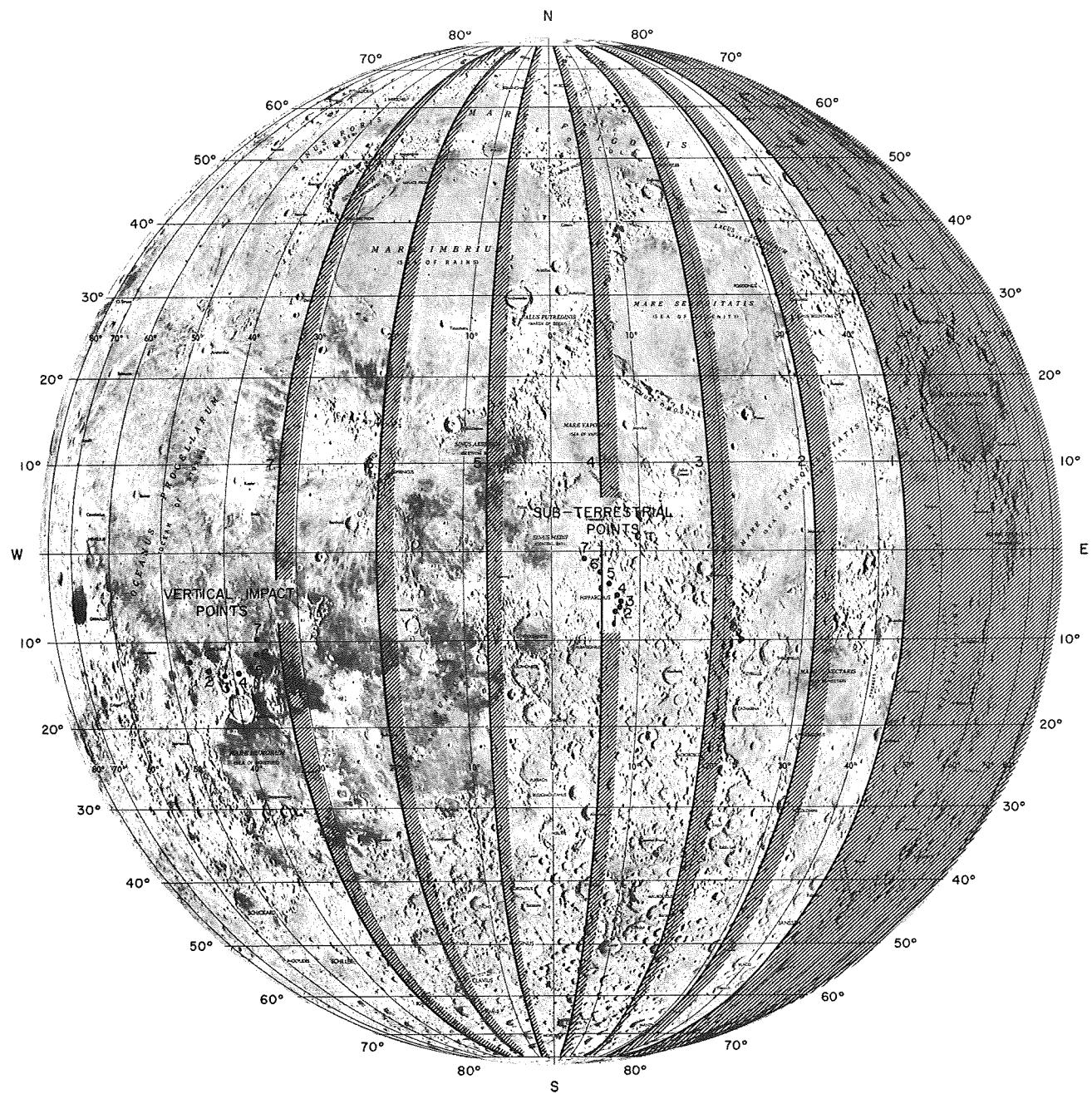


Fig. 40. Velocity and altitude vs. time from  
lunar impact,  $V_I = 2.7$  km/sec

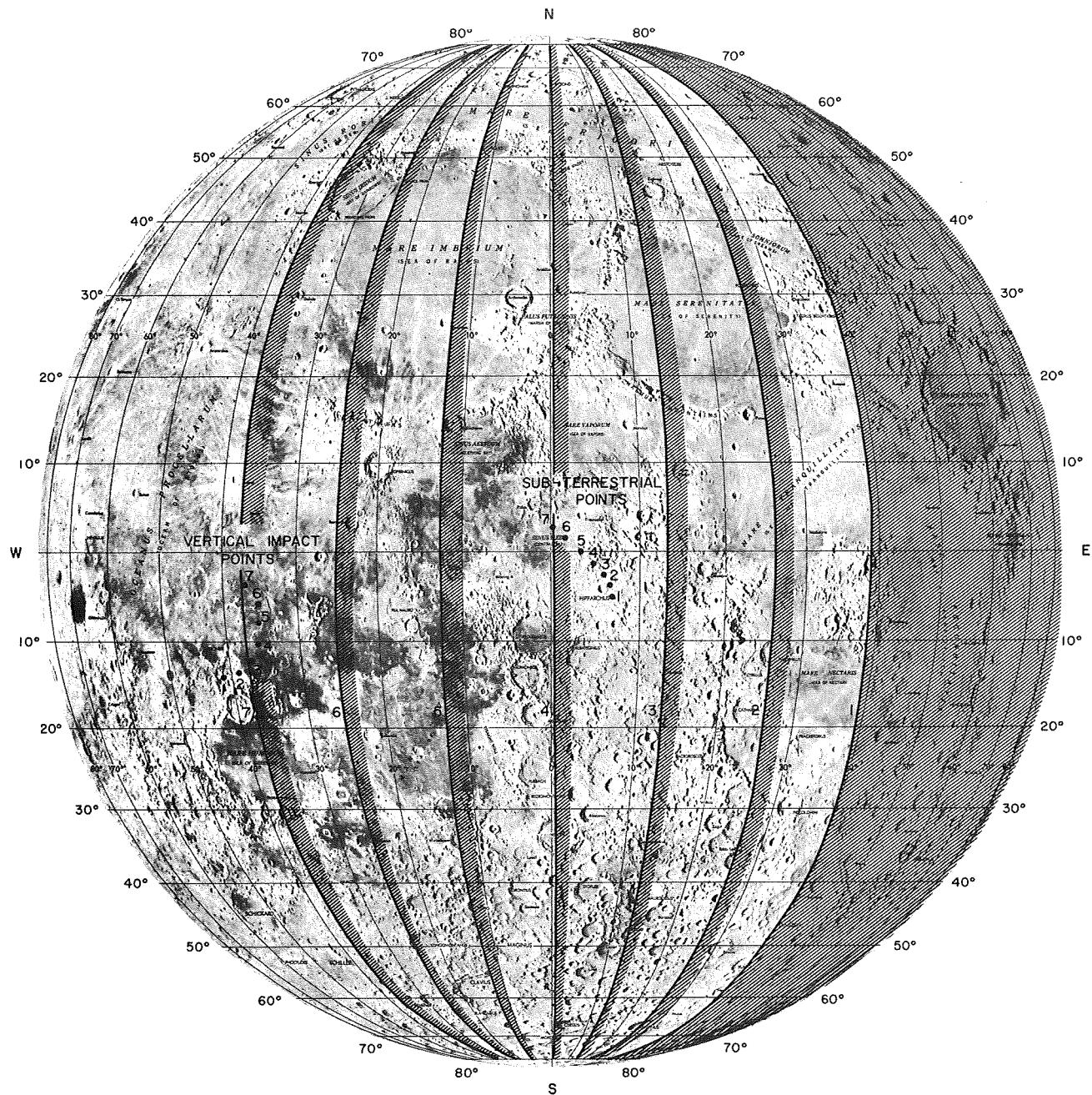
Fig. 41. Flyby parameters vs. the miss parameter  $B$



CORRESPONDING  
I.D. LAUNCH DATE

1	JAN 18,	1965
2	JAN 19,	1965
3	JAN 20,	1965
4	JAN 21,	1965
5	JAN 22,	1965
6	JAN 23,	1965
7	JAN 24-25,	1965

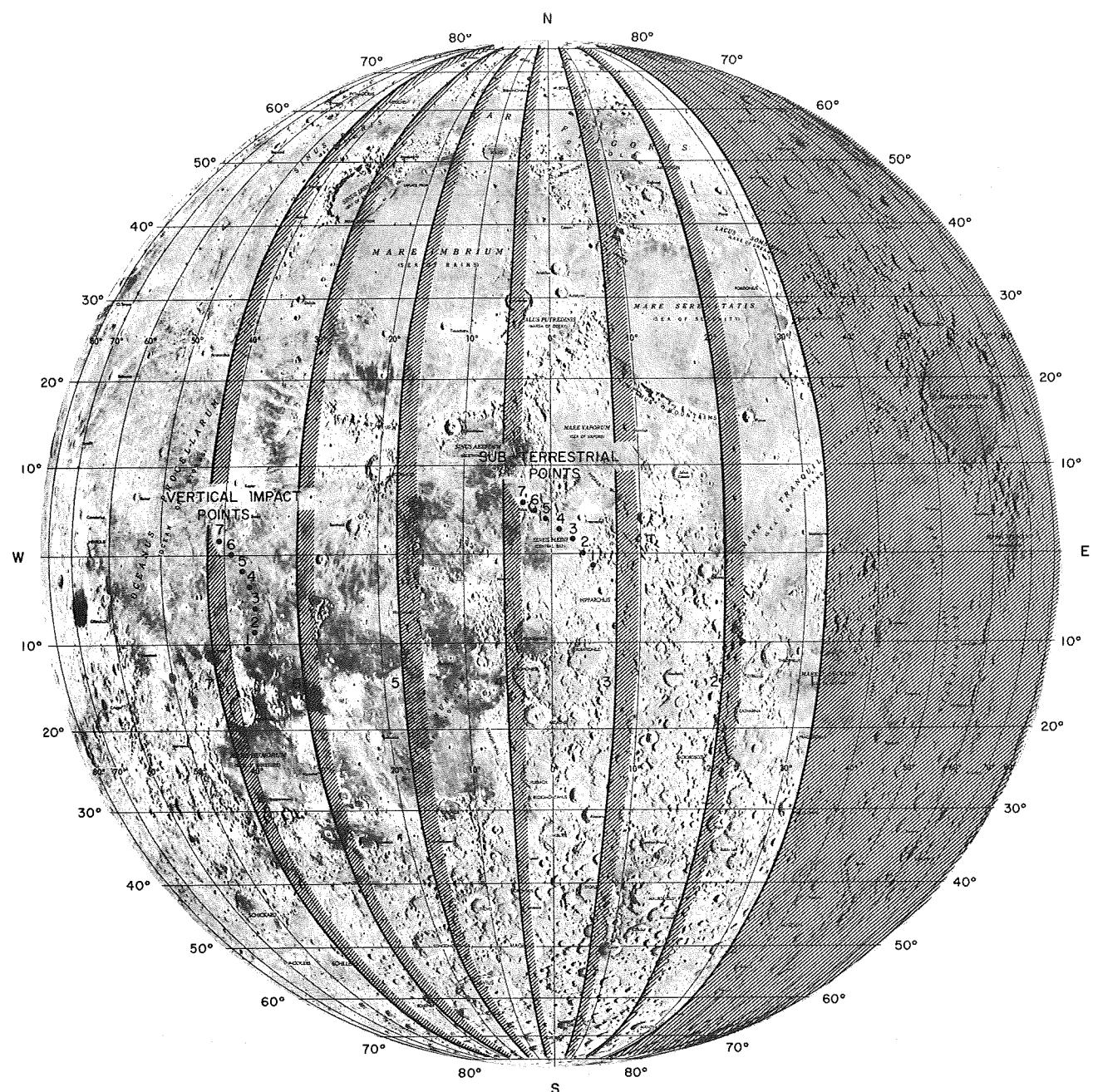
Fig. 42. Lunar lighting and trajectory geometry at impact  
for January launch period



CORRESPONDING  
I. D. LAUNCH DATE

1	FEB 17,	1965
2	FEB 18,	1965
3	FEB 19,	1965
4	FEB 20,	1965
5	FEB 21,	1965
6	FEB 22-23,	1965
7	FEB 24,	1965

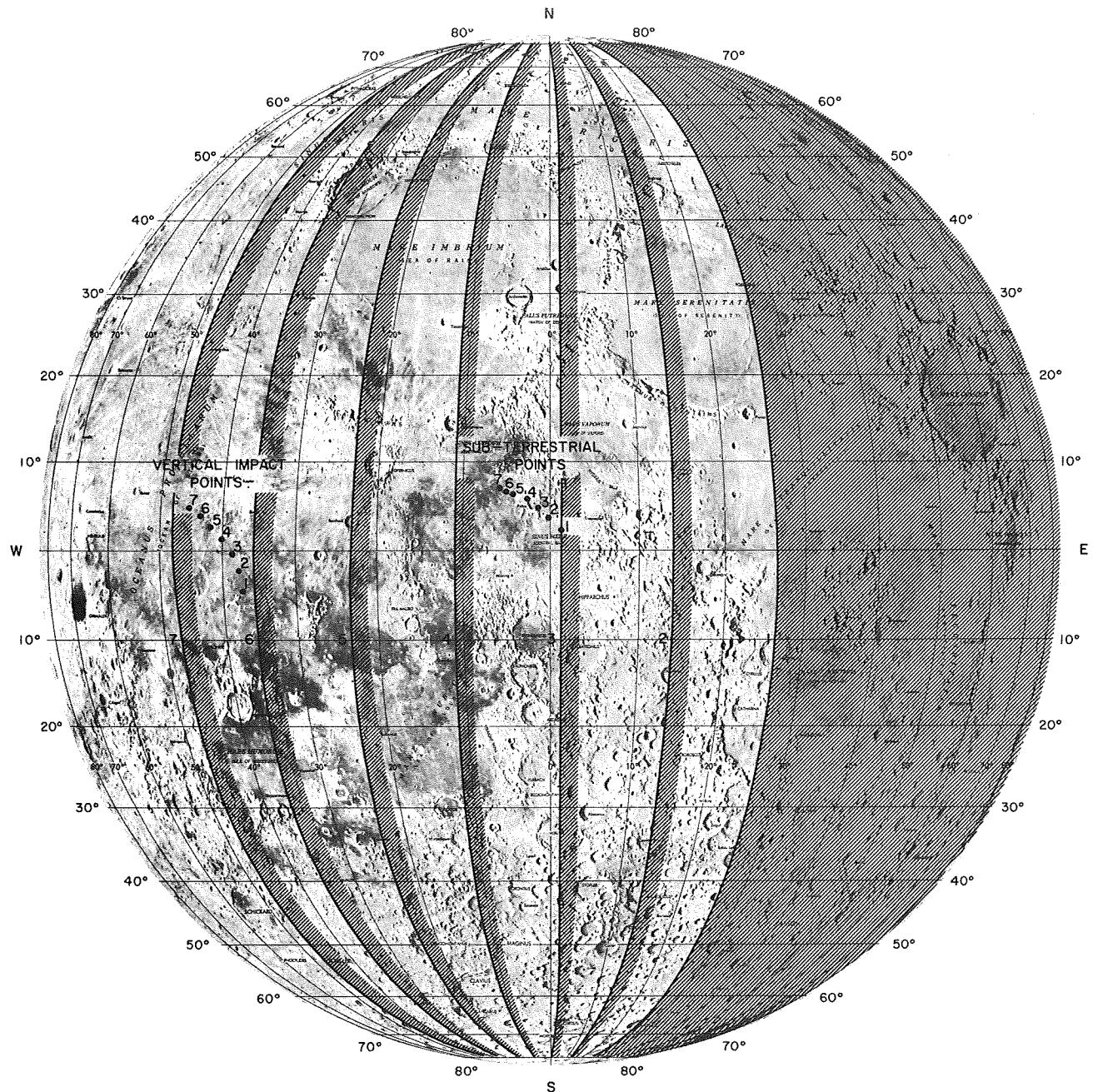
Fig. 43. Lunar lighting and trajectory geometry at impact  
for February launch period



CORRESPONDING  
I.D. LAUNCH DATE

1	MAR 19,	1965
2	MAR 20,	1965
3	MAR 21,	1965
4	MAR 22	1965
5	MAR 23,	1965
6	MAR 24-25,	1965
7	MAR 26,	1965

Fig. 44. Lunar lighting and trajectory geometry at impact  
for March launch period



I.D.	CORRESPONDING LAUNCH DATE
1	APR 18, 1965
2	APR 19, 1965
3	APR 20, 1965
4	APR 21, 1965
5	APR 22, 1965
6	APR 23, 1965
7	APR 24, 1965

Fig. 45. Lunar lighting and trajectory geometry at impact for April launch period

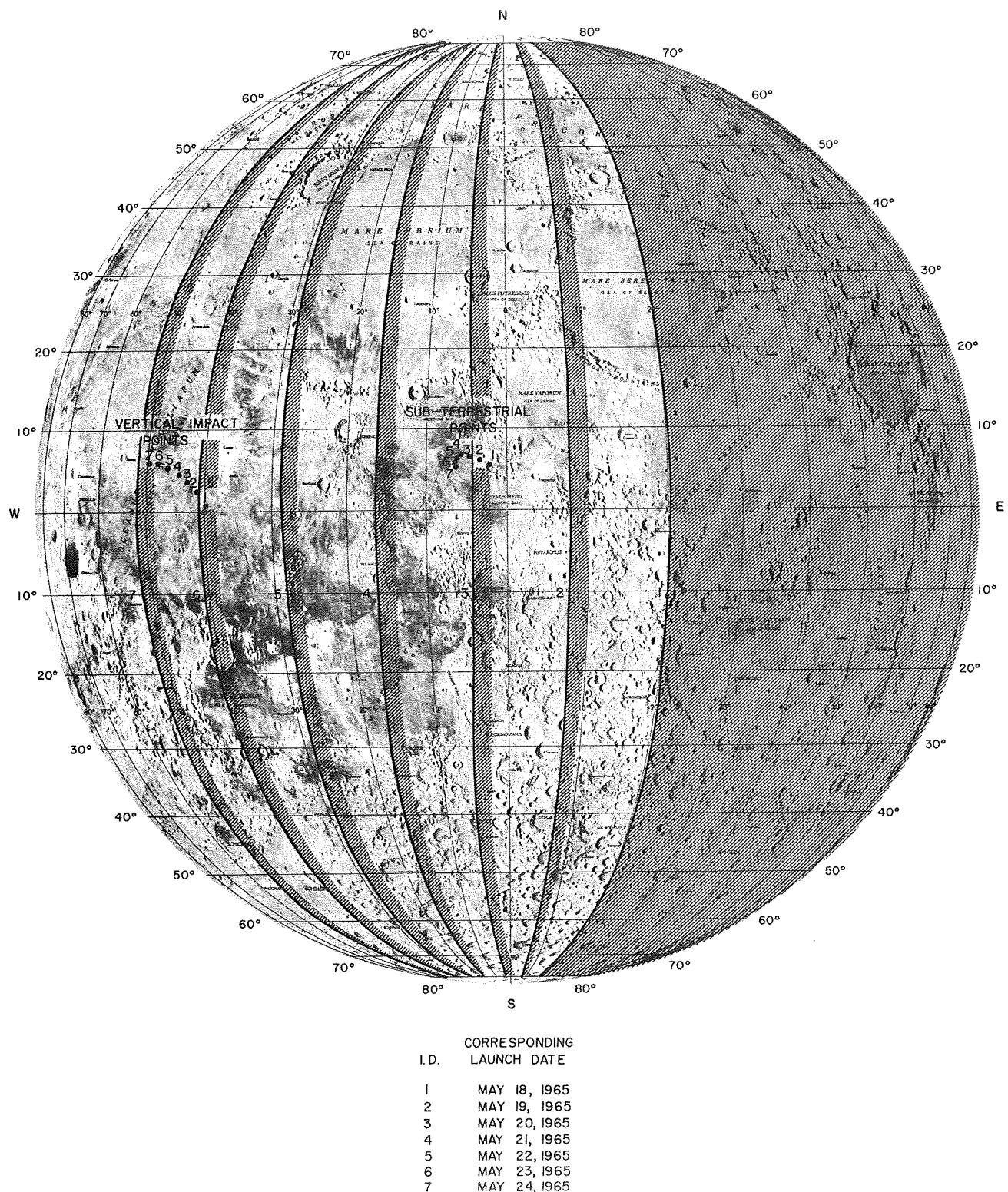


Fig. 46. Lunar lighting and trajectory geometry at impact for May launch period

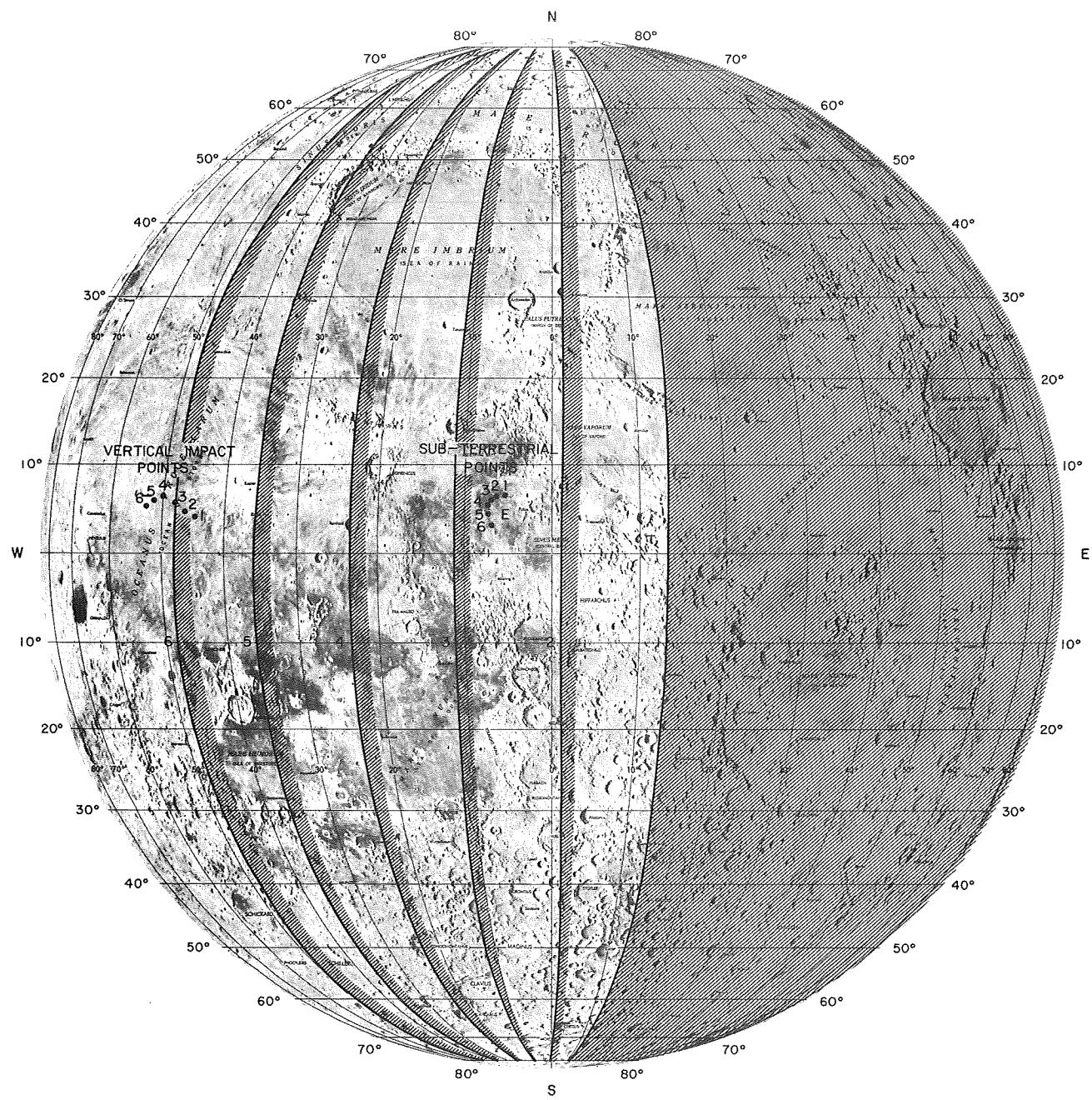
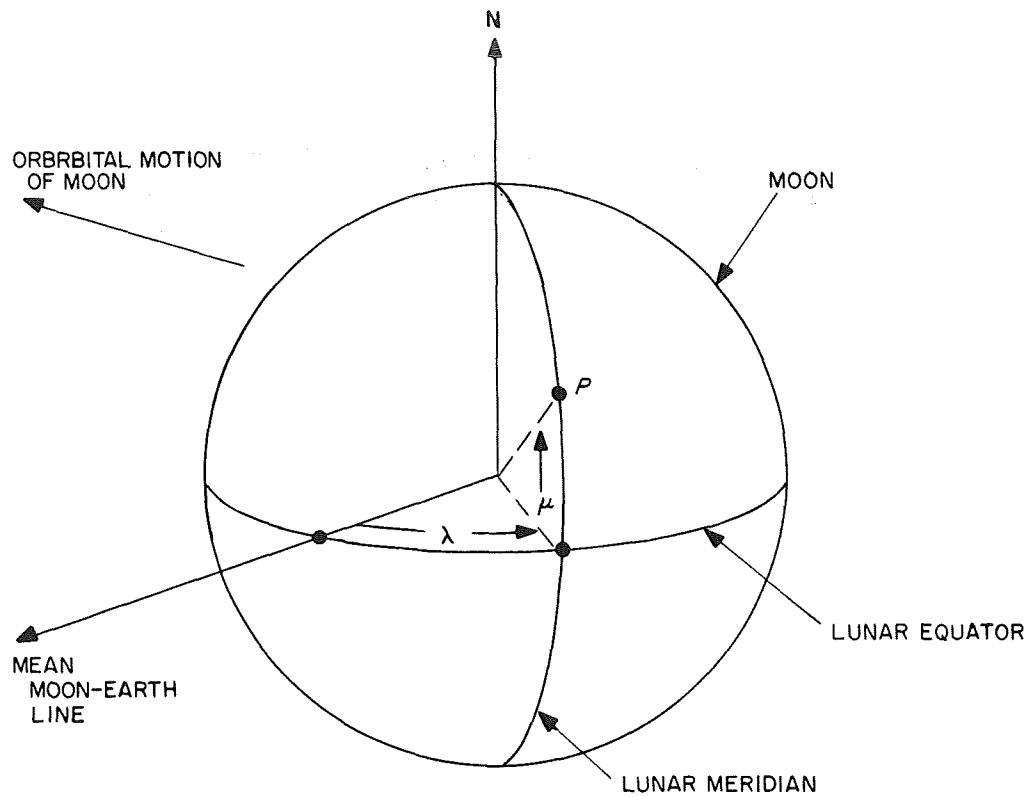


Fig. 47. Lunar lighting and trajectory geometry at impact for June launch period



NOTE:

THE SELENOGRAPHIC LONGITUDE ( $\lambda$ ) AND LATITUDE ( $\mu$ ) FOR THE POINT  $P$  ON THE MOON'S SURFACE ARE SHOWN IN THE POSITIVE DIRECTIONS RESPECTIVELY

THE SELENOGRAPHIC COORDINATES OF THE TRUE MOON-EARTH ARE TIME VARIANT

Fig. 48. Definition of selenographic coordinates